



Middle East Teachers of Science,
Mathematics and Computing

METSMaC 2007

METSMaC 2007

‘Active teaching, Active learning’

Proceedings of the Third Annual Conference
for Middle East Teachers of
Science, Mathematics and Computing

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Preface

These proceedings contain a selection of papers presented at the Third Annual Conference for Middle East Teachers of Science, Mathematics and Computing – METSMaC 2007 – which was held at the Beach Rotana Hotel & Towers in Abu Dhabi between 17–19 March 2007. The option to submit a manuscript for these proceedings was open to all presenters. On receipt, each paper was subject to a rigorous peer-review process and those papers accepted appear herein.

This year's conference built on the success of previously held METSMaC conferences. Attracting just under 300 delegates from across the region and beyond, METSMaC has rapidly established itself as the leading educational conference within the Gulf region. It provides a forum wherein teachers, lecturers, and educators can come together to share and exchange experiences, learn about new and innovative ideas, discuss current pedagogical best practices, or to simply sit back, relax and mix with like-minded colleagues. As the conference continues to grow in stature its outlook for the future looks bright.

In a departure from previous conferences, a new *engineering education* track was added and extended the reach of the programme to the five technical areas of mathematics, the four sciences of physics, chemistry, biology and geology, engineering, computing, and interdisciplinary. The addition of this new and highly relevant track was intended to explore the evolving needs of engineering education over the coming decade and address curriculum development and interactive learning specific to graduating engineers in the Gulf region.

The conference sought to promote the continued renewal and improvement of student learning and achievement in schools, colleges and universities; an idea reflected in this year's conference theme of *Active Teaching, Active Learning*. Taken together, the papers found in this volume live up to this noble aim. In the plenary and keynote papers one finds encouraging words, conveyed with all the enthusiasm of the young at play, of how we as teachers can inject new energy and vigour into our teaching. The contributed papers are also far from quiescent. Here again one finds ideas and suggestions which places the learner, our students, at the centre of the teaching process. Effective teaching remains an ongoing challenge and requires constant commitment and dedication on the part of the teacher. The wealth of ideas, suggestions, approaches and strategies highlighted in many of the papers contained within this volume are however sure to inspire those who take the time to delve a little beyond the first few pages of these proceedings.

The forty-two papers making up this volume represent a wide range of submissions received from teachers teaching across many different countries and under equally diverse educational settings. Within these pages one finds authors teaching in the following countries: Brunei, Kuwait, Qatar, Saudi Arabia, Sultanate of Oman, United Arab Emirates, United Kingdom, and the United States of America. As was done in preceding years the volume has been divided into two parts. The first part contains those papers submitted by the plenary and keynote speakers while the second part consists of accepted contributed papers. For ease of reference the contributed papers are further divided into the five technical areas reflected in the conference programme of Mathematics, Science, Engineering, Computing and Interdisciplinary. The number of accepted papers represents a significant increase on previous years and is an encouraging sign of the growing importance and recognition the conference is gaining within

the wider Gulf region.

METSMAc 2007 featured one plenary speaker and an invited speaker for each of the five technical tracks. The invited talks were interspersed throughout the conference programme over the course of the three days. Each of the speakers were internationally recognised as leading educational experts within their chosen fields of endeavour. The speakers were Mr Douglas Butler, Plenary Speaker, Oundle School, United Kingdom; Professor David Tall, Keynote Mathematics Speaker, University of Warwick, United Kingdom; Dr Norman Reid, Keynote Science Speaker, University of Glasgow, United Kingdom; Dr Stephen Heppell, Keynote Computing Speaker, Heppell.net, United Kingdom; Mr David Graddol, Keynote General Speaker, The English Company Ltd, United Kingdom; and Dr Michael Ohadi, Keynote Engineering Education Speaker, Chief Academic Officer and Acting Executive Director, The Petroleum Institute, United Arab Emirates. In addition to the invited speakers there were a total of seventy contributed oral presentations and seventeen contributed poster presentations.

The conference was held under the patronage of His Excellency Yousef Omair bin Yousef, Secretary General of the Supreme Petroleum Council, Chief Executive Officer of Abu Dhabi National Oil Company, and Chairman of the Governing Board for The Petroleum Institute. It was organised and hosted by The Petroleum Institute in Abu Dhabi in association with the National Bank of Abu Dhabi. Dr James Leanderson and Mr Michael Giblin served as the Conference and Organising Committee Chairs respectively. The generous financial support and sponsorship of the conference from our sponsors, National Bank of Abu Dhabi (NBAD), The Petroleum Institute, Abu Dhabi National Oil Company (ADNOC), and Edutech are also gratefully acknowledged.

Editors

Seán Stewart, Janet Olearski, Peter Rodgers, Douglas Thompson and Emer Hayes

Plenary and Keynote Papers

What can technology add to mathematics and science teaching?

Douglas Butler

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Abstract

Mathematics and science have been taught very successfully for many centuries with just a piece of chalk. In this paper, I will argue that maybe it has been just the more able pupils who really mastered the subjects from this approach, and that there are new opportunities now to help the less mathematically and scientifically endowed to visualise what is going on. The motivational prospects of using Information and Communication Technology in the classroom are profound. Exciting web resources and dynamic software can be used to bring a new realism into the subjects, and to help teachers answer the dreaded ‘why are we learning this?’ type of question.

Introduction

Mathematics and science have been taught very successfully for many centuries with just a piece of chalk. This paper will argue that maybe it has been just the more able pupils who really mastered the subjects from this approach, and that there are new opportunities now to help the less mathematically and scientifically endowed to visualise what is going on.

The motivational prospects of using Information and Communication Technology (ICT) in the classroom are profound; exciting web resources and dynamic software can be used to bring a new realism into the subjects and can help teachers answer that question they all dread: why are we learning this?

Drawing on experiences gained from over thirty years at the chalkface, and particularly on the author’s keen involvement over the past ten years in helping teachers to harness new technologies, this paper will explore ways teachers of mathematics and science can add new sparkle to their teaching through currently available technologies.

What technology?

This has to be the first question. Unless it is available to all, it could be argued that we should not be talking about it. The debate should then be confined to the merits of using affordable hand-held graphics calculators in the classroom, and much has been written about this. Calculators, without doubt, do offer a wide range of learning experiences for pupils in mathematics and science. The technology is theirs, and ownership

is important, not just of the technology but also of what they do with it by way of the calculations they make.

As computers and Internet connections become more widespread in schools and universities, the time is right to consider what an amazing addition they can be to the classroom experience. Bringing the Internet and powerful software into pupils' lives is, after all, the classroom equivalent of the web-connected computer that already sits on most people's desks these days in the workplace, the same workplace that we are preparing our pupils for.

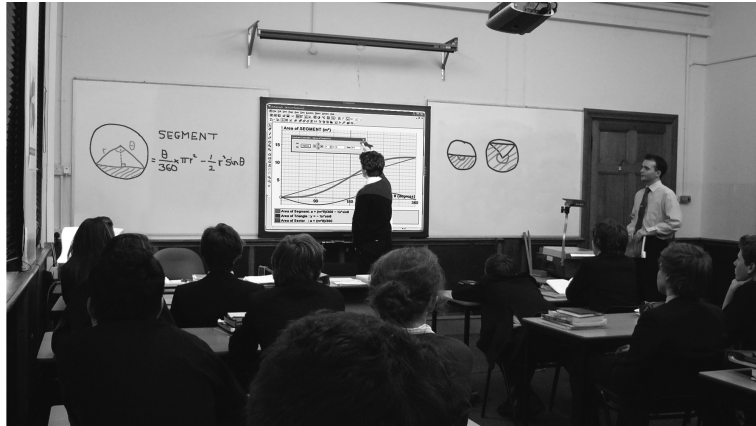


Figure 1: A typical classroom at Oundle School, with an interactive whiteboard in use with dynamic software and resources from the Internet.

The key, of course, is the availability of affordable data projectors, and although these still remain a distant dream for many teachers, there are encouraging signs of prices falling. Besides this, there are many possibilities for both the surface that it displays onto (interactive whiteboards, etc.) and the way the signal gets there (tablets, etc.). Whatever the method, the teacher may appear to have ownership of the technology, so it is vital that the pupils feel fully interactively involved with the content. An example of a technology-rich classroom environment from the author's home institution is shown in Figure 1.

So how can all this technology be put to work successfully? Can it enhance the learning experience in science and mathematics? Can it ultimately have an effect on what is taught? This latter question is a fascinating area that will continue to be the subject of a lot of discussion elsewhere, so let us look at some of the possibilities currently available for today's classroom.

The history of mathematics and science

Both mathematics and science have incredibly rich histories and a web-connect screen in the classroom gives the ideal opportunity to slip some of it seamlessly into a lesson without it seeming like a history lesson! For example, a Pythagoras lesson can be

greatly enriched by a visit to the TSM Resources site¹ where you can find out about the amazing Tunnel of Samos² that was constructed in Pythagoras' time by starting at both ends (And when was that? And where is Samos?).

The web itself is a mathematical and scientific miracle

Try this. On your PC, go to 'Start' => 'Run' and type `cmd` in the 'command line'. Then type `tracert www.yourwebsite.com` Something remarkable happens. It traces out the route that the web takes to link your computer to that website, and gives you the nodes and times. Google itself is a fascinating application of applied mathematics with its search engine giving results from over twenty billion pages almost instantaneously.

The mystery of mathematics

Technology can certainly help to unravel some of the mystery of mathematics. For example, the multifarious golden ratio can be explored in so many ways, including the human body, the Parthenon, and a credit card (see Figure 2)! For inspiration try Gary Meisner's *Golden Number site*.³

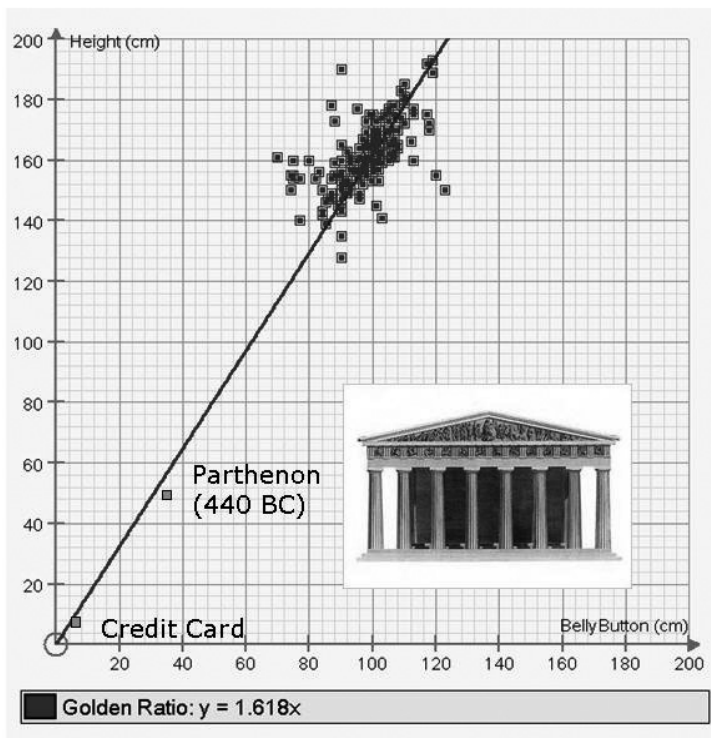


Figure 2: Data from a classroom experiment to measure the ratio of height to belly-button, together with some other golden ratio favourites!

¹TSM Resources (Oundle), available at: www.tsm-resources.com

²<http://pr.caltech.edu/periodicals/EandS/articles/LXVII1/samos.html>

³<http://goldennumber.net>

The mystery of calculus

The graphical approach offered by dynamic software can certainly give another layer of opportunity for tricky concepts to be understood better. Being able to zoom in on 500 rectangles under the curve $y = x^2$ on the closed interval $[2, 4]$ illustrates a principle that can be very hard to get across by traditional means (see Figure 3). Extend this to three dimensions and a whole new world opens up, making the study of volumes of revolution a natural follow-on from areas (see Figure 4).

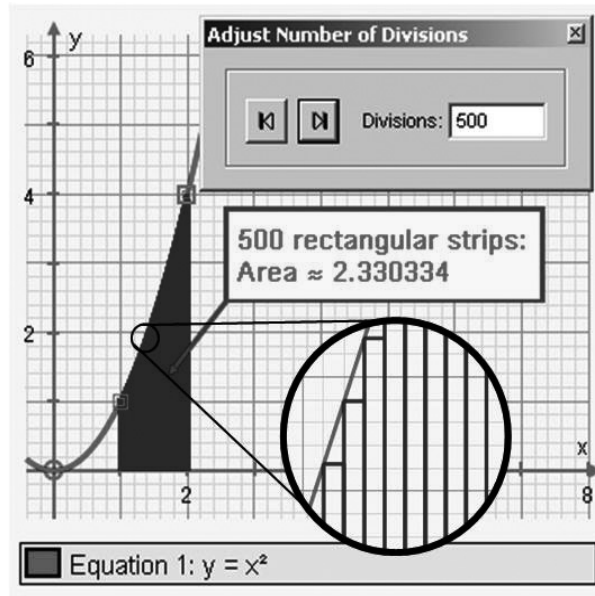


Figure 3: Calculation of the area under a curve by dividing the region up into many small rectangular strips.

Another application of the calculus is differential equations, usually regarded as the province of only the brightest in secondary schools. Once the principle of a rate of change of one variable with respect to another has been grasped, there is no reason why a graphical approach should not be used to bring this topic to life for even modest pupils.

Fascinating applications include falling out of an aeroplane and predator-prey situations. If students cannot solve the equations, they can certainly see what is going on. This is surely the equivalent to the numerical approach that is widely adopted by problem solvers in the 'real' world. In Figure 5, with Newton's second law of motion understood, this simple first-order differential equation for the free-fall motion of a skydiver falling through air is easily formed. Figure 6 shows how pupils can then have fun trying to deduce the terminal velocity of the falling skydiver by varying parameters such as the mass of the diver m , the resistive constant k , and the type of resistance n ($n = 1$ is linear resistance, $n = 2$ quadratic, and so).

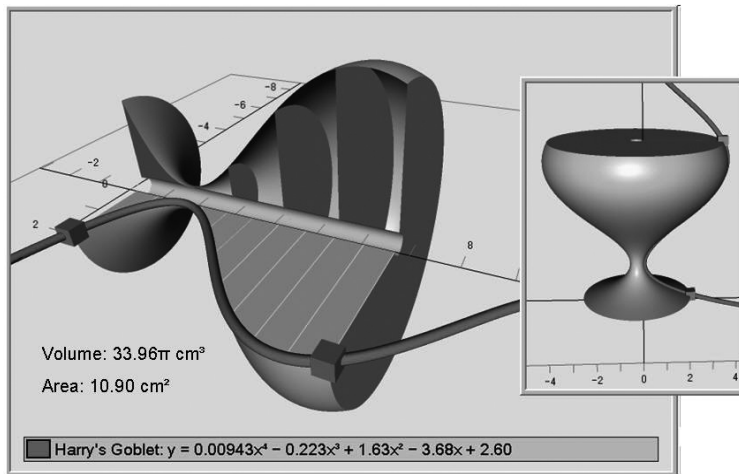


Figure 4: Autograph can now explore fully what is going on when an area is rotated about an axis to form a volume. Here, the volume of Harry Potter's goblet, being a solid of revolution, is calculated.



Figure 5: To the right is a free body of the forces which act on a skydiver, to the left, when he or she jumps from a plane.

I hate vectors!

Pupils in England have long found vectors troublesome, mainly because they could not easily visualise how vectors worked. However, we now have dynamic tools which can

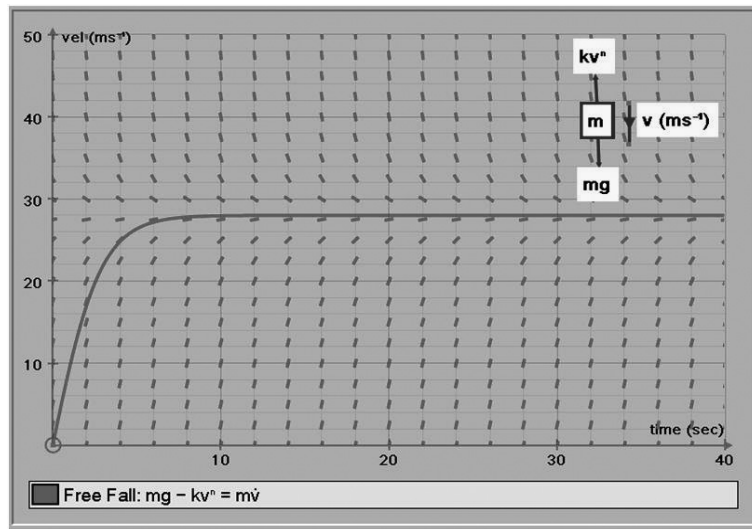


Figure 6: Graphical determination of the terminal velocity of a skydiver when the parameters m , k and n are varied.

illustrate vectors beautifully (see Figure 7). Since vectors need their own algebra, this can be introduced very effectively by dragging points around the screen. As with areas and volumes, the extension to three dimensions is trivial, and even the ‘scariest’ cross products become de-mystified!

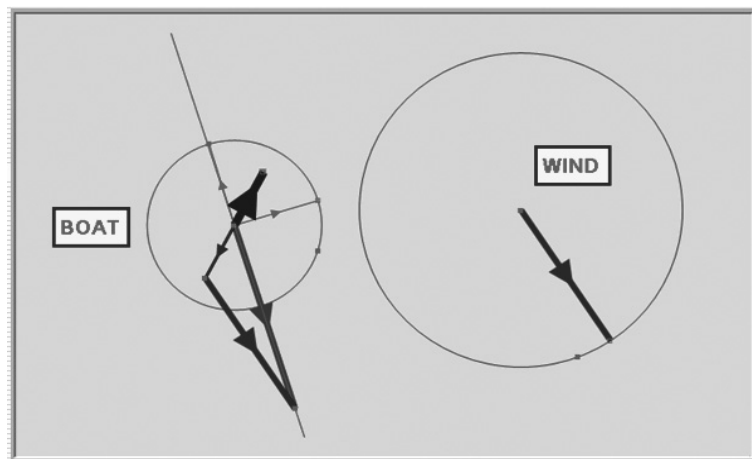


Figure 7: Sailing is all about vectors and the direction of the ‘apparent’ wind – a nice application of the vector difference.

Mathematics in films

The film industry is now a major employer of mathematical talent, requiring a fluent ability to think and work in three dimensions (see Figure 8). As things stand, most school pupils only experience shapes and transformations in two dimensions, but the extension to three dimensions with the right software can be an eye-opener. What is more, they can understand what is going on!

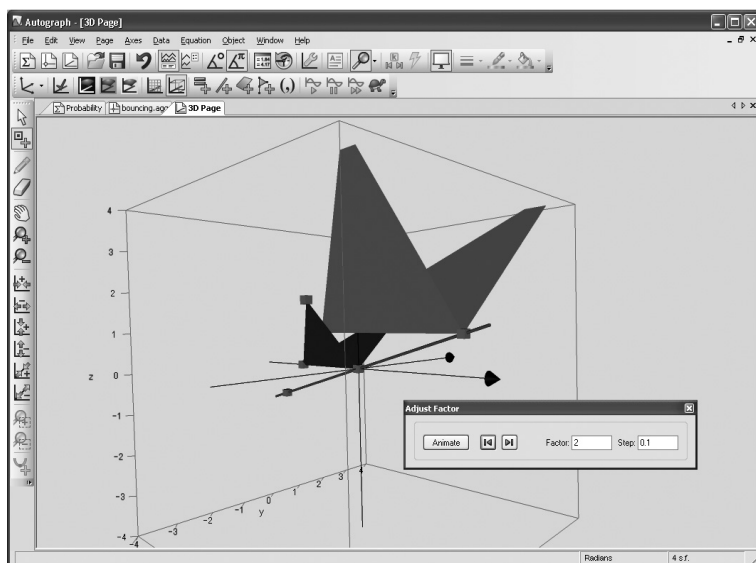


Figure 8: Three-dimensional film animations are a good example of the principle that the triangle is the building block of all three-dimensional surfaces.

Films about mathematics

It is always interesting to look out for films that feature mathematics in their plot. The list is longer than you might think and includes: *Numb3rs* (CBS TV, 2006); *Proof* (2005); *A Beautiful Mind* (2001); *PI* (1998); *Good Will Hunting* (1997); *Sneakers* (1992); and *Stand and Deliver* (1987). Particularly impressive is the support that Texas Instruments is giving to the *Numb3rs* TV series, so that pupils have excellent worksheets based on recent shows.

Data, data everywhere

The world is heaving with data. Therefore, it is all the more important to be able to manage them in the classroom and inspire the young to take an interest in how data sets can be interpreted and how essential they are in everyday decision making.

The basis of a significant proportion of data sets is the normal distribution. Why, for example, on check-in at the airport do they weigh our luggage but not us? One way to illustrate the importance of the normal distribution is to use a simple simulation that takes samples of size 1, 2, 3, ... from a set of basic data, e.g. the numbers 1 to 6. This will show that as the sample size gets larger, the distribution of the sample means is normal.

This can go some way to explaining why so many naturally occurring distributions are normal (see Figure 9).

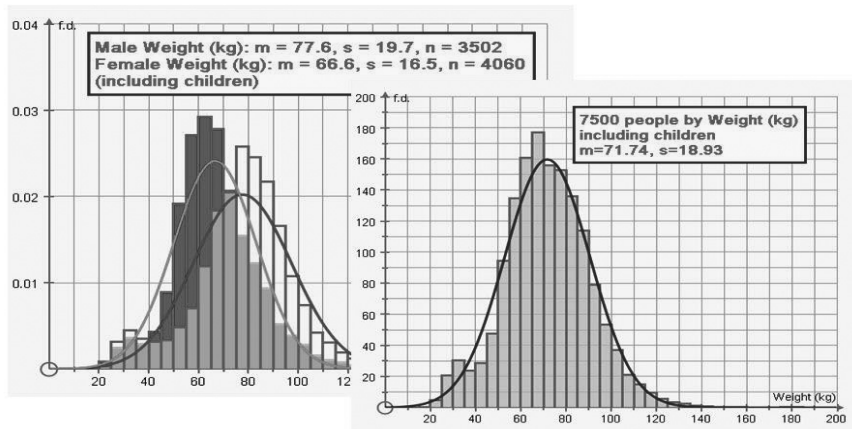


Figure 9: The normal distribution is everywhere! Here is the data from the 7500 patients at the Oundle surgery: on the left, male, female and children, and on the right, all put together. So if 400 of these people turn up to board a plane, their total weight is very predictable.

Spreadsheet skills

Clearly the subject of another article, but any review of technology in mathematics and science education must mention Excel and how fundamentally important it is as a calculating and modelling tool. In our annual three-day TSM workshop,⁴ over twenty-five per cent of the courses are on Excel.

Scientific and mathematical word processing skills

Teachers and pupils alike need to become fluent in using standard word processors to create mathematical and scientific expressions, and handsome diagrams. The skills required for this are not obvious, but in many ways essential. It could be argued that curriculum time should be found for this and this will have serious implications for teacher training (as an example, see Figure 10).

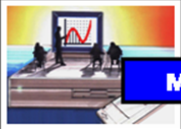
Having fun with Google Earth

Google Earth⁵ is freely available to anyone with a reasonably fast computer and Internet connection, and offers the opportunity for an exciting new range of screen-based classroom activities. If you also download the Screen Protractor⁶ you can easily measure angles of familiar objects around the world, for example the Pentagon in Washington. This protractor is far easier to use on screen than the usual D-shape hand-held protractor, which does not lend itself to screen use so well.

⁴TSM Workshop to be held at Oundle School, 10–12 July 2007 www.tsm-resources.com/tsm-07

⁵<http://earth.google.com>

⁶Iconico Screen Protractor available from: www.iconico.com/protractor



Making WORD Mathematically Friendly

FORMULAE AS TEXT: Use (unicode) text characters on one line where possible:

eg: $y = x\sqrt{1-x^2}$ $y = \pi \pm \sin^{-1}(\frac{1}{2}x)$ $\sigma^2 = (1/n)$
 $y = e^{\sin^2 x}$ $\int \sin^2 \theta d\theta = \frac{1}{2}\theta(1 - \cos 2\theta) = \frac{1}{2}\theta - \frac{1}{4}\sin 2\theta$
 $\chi^2 \sim N(\mu, \sigma^2)$ $\int \sin^2 \theta \cos \theta d\theta = \frac{1}{3} \sin^3 \theta + c$

THE EQUATION EDITOR

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

THE DRAWING TO

CUMULATIVE FREQU

Figure 10: Making Word mathematically friendly!

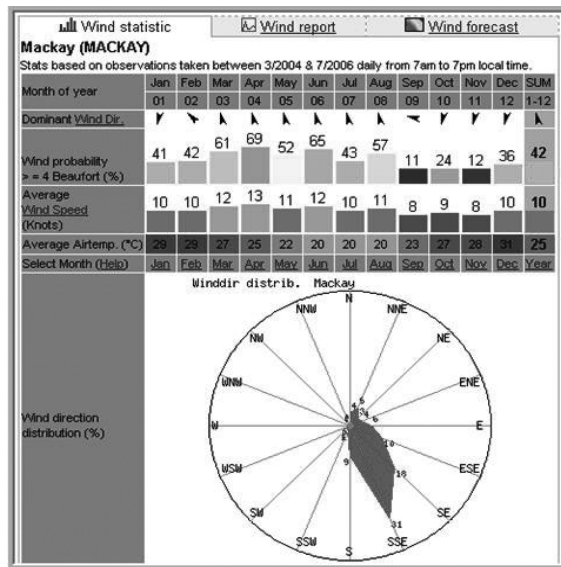


Figure 11: The wind statistics averaged over the year for the single runway Mackay airport in Queensland. Clearly, with planes preferring to take off into the wind, that should indicate the direction of the runway.

Another lovely application to explore is the direction of airport runways, as indicated by the number painted in large letters on the end. This number gives the direction

of the runway in tens of degrees from North (e.g. 'Runway 20' is at 200° clockwise from North, i.e. S20W). This got me wondering how they decide on the direction to build it in the first place. It must have something to do with the prevailing winds.

Back to Google, a marvellous site called Wind Statistics⁷ gives what are best described as circular histograms for the wind by month and over the year as a whole (see Figure 11). The results for Mackay Airport in Queensland, Australia were very satisfying.

Conclusion!

It is not really worth comparing classrooms with and without a web-connected projector. You have got what you have got and mathematics and science teachers the world over are doing magical things to inspire the young using whatever comes to hand. It is important too not to forget that both subjects have been taught with just a piece of chalk for centuries! All I do know is there seems to be growing anecdotal evidence that teaching mathematics and science with dynamic images can make the lessons more effective, more efficient, and certainly more fun!

⁷www.windfinder.com/windreports/windkarte_world.htm

Teachers as mentors to encourage both power and simplicity in active mathematical learning

David O. Tall

Institute of Education, University of Warwick, Coventry, United Kingdom

Introduction

The teaching of mathematics is under stress around the world. Imposed targets in many countries press teachers to train their students to obtain higher marks on national tests. ‘Teaching to the test’ can produce higher marks on standard questions, but is often accompanied by a sense of disappointment that many students have not understood what they have learnt. Techniques taught sequentially may enable the individual to *do* mathematics, but not necessarily to *think* about it, making the mathematics grow increasingly complicated.

This paper considers how flexible knowledge can be built by focusing on essential detail that leads to rich concepts that are both powerful and yet simple to use. This arises through a process that the Fields’ Medallist Thurston (1990) called ‘compression of knowledge’. I theorise that focusing on essential ideas can lead to ‘thinkable concepts’ that are easier to manipulate mentally and to link together in a more powerful conceptual structure. Over the long term, students who form rich compressed ideas are more likely to be able to build on them in a simpler way than students who learn procedures just to pass tests. As a consequence, this suggests that teachers need to act as mentors to encourage their students to build thinkable concepts that link together in coherent ways.

Compression of knowledge and powerful mathematical thinking

For many individuals, mathematics is *complicated* and it gets more complicated as new ideas are encountered. For others, by focusing on the essential ideas, it becomes possible to see mathematics in a more focused way that makes many ideas essentially more simple. As my colleague, and founding Chairman of the Mathematics Institute at Warwick, Christopher Zeeman (1977), said ‘Technical skill is mastery of complexity, while creativity is mastery of simplicity’.

The way in which complicated ideas can become simple to those who conceive them in a focused way is explained beautifully by Fields medallist, William Thurston:

Mathematics is amazingly compressible: you may struggle a long time, step by step, to work through some process or idea from several approaches. But once you really understand it and have the mental perspective to see it as a whole, there is often a tremendous mental compression. You can file it away, recall it quickly and completely when you need it, and use it

as just one step in some other mental process. The insight that goes with this compression is one of the real joys of mathematics (Thurston, 1990, p. 847).

Examples of compression occur throughout the learning of mathematics, starting with the child learning the highly complicated action of counting the items in a collection, which is steadily compressed into the concept of number. Symbols in arithmetic, algebra, trigonometry, calculus, and so on, also usually have two complementary meanings:

- as a *process* to be carried out by some procedure of calculation or manipulation,
- as a *concept* in its own right, to be thought of as a mental object that can be manipulated, as symbols are manipulated in arithmetic or algebra.

As a *process*, it allows us to *do* mathematics. As a *concept*, we are able to *think about it* and make connections to other thinkable concepts in flexible ways. A partial list of symbols in mathematics that represent both process and concept is given in Table 1.

symbol	process	concept
4	counting	number
$3+2$	addition	sum
-3	subtract 3 (3 steps left)	negative 3
$3/4$	sharing/division	fraction
$3+2x$	evaluation	expression
$v = s/t$	ratio	rate
$y = f(x)$	assignment	function
dy/dx	differentiation	derivative
$\int f(x)dx$	integration	integral
$\lim_{x \rightarrow 2} \frac{x^2 - 4}{x - 2}$ $\sum_{n=1}^{\infty} \frac{1}{n}$	tending to limit	value of limit
$(x_1, x_2, \dots, x_n)$	vector shift	point in n -space
$\sigma \in S_n$	permuting $\{1, 2, \dots, n\}$	element of S_n

Table 1: Symbols as process and concept (taken from Tall, Gray, Bin Ali, Crowley, DeMarois, McGowen, Pitta, Pinto, Thomas and Yusof, 2001).

Symbols as procepts

A symbol acting dually as a process (to *do* mathematics) and a concept (to *think about*) is called an *elementary procept* (Gray and Tall, 1994). However, different symbols, such as 6, or $4+2$ or $1+5$ or $5+1$, or 2×3 all represent essentially the same thing. This is

called a *procept*. A procept can be broken into its constituents and reassembled in many flexible ways. For example, to calculate $8+6$, one may know that $8+2$ is 10, and breaking the 6 into $2+4$ allowing the 2 to be added to the 8 to get 10, then the 4 is added to 10 to get 14. It is for this reason that we allow the procept to be represented by different symbols, such as $4+2$, $2+4$, $7-1$, provided that each symbol is just a different way of writing the same underlying concept. Gray and Tall found that young children learning arithmetic developed in a spectrum of different ways. The more successful could think of numbers as flexible procepts, deriving new number facts from old ('I know 7 and 5 is 12' so '12 take away 5 is 7') while others remained in the safety of counting which becomes time-consuming ('12 take away 5 is ... 11, 10, 9, 8, 7'). In the mathematics classroom we spend a great deal of time teaching students procedures: column addition, long multiplication, procedures to solve equations by 'doing the same thing to both sides' leading to rules such as 'change side, change sign'. In calculus we meet the rules of differentiation where ' $d(uv) = vdu + u dv$ ' is used to differentiate a product by replacing u and v by formulae and working out the symbolic derivative; then we move on to develop procedures for integration. I suggest that the idea of using symbols flexibly as 'do-able' process or 'thinkable' concept is what makes mathematics essentially simpler at successive levels of sophistication.

Different ways of interpreting symbols

Let me ask a fundamental question. Do you personally see the formulae $x(x+2)$ and $x^2 + 2x$ as being 'the same' or 'different'? Think about it for a while. As procedures they are *different*. The first adds x and 2, then calculates x times the result; the second squares x , also multiplies 2 times x , then adds the two results together. As procedures they involve *totally different* sequences of operations. As algebraic expressions, we often say that they are *equivalent*. There are several reasons for this. First, as a procedure of evaluation, for a given numerical value of x , the two *always* give the same numerical output. Secondly, the equation $x(x+2) = x^2 + 2x$ is true for all x and is often referred to as an *identity*. Thirdly, if one shifts one's focus of attention from the successive steps of a procedure to the *effect* of the procedure, then the two procedures of evaluation *have the same effect*. Finally, when a function is defined to be the set of ordered pairs

$$\{(x, y) \in \mathbb{R}^2 \mid y = f(x), x \in \mathcal{D}\}$$

then the functions

$$f(x) = x(x + 2), \quad g(x) = x^2 + 2x,$$

are, by definition, exactly the same function on the domain $\mathcal{D} = \mathbb{R}$.

Compression from procedure to process to procept

In the mathematics education literature, a distinction is often made between a *procedure* and a *process*, by defining a procedure to be a specific set of steps and a process to be a transformation as a whole (Davis, 1983, p. 257). This means that a particular process may be carried out by several different procedures. With this interpretation, an algebraic expression may be considered as a specific *procedure* of evaluation, or, if we allow

ourselves to think of equivalent expressions—such as $x(x + 2)$ and $x^2 + 2x$ —as being ‘the same’, then they are just different ways of writing the same *process*. At another level, by thinking of the expressions as functions that are both processes to evaluate and concepts to be mentally manipulated, the expressions now act as *procepts*. As procepts, two functions u and v can be operated on to obtain their sum $u + v$, difference $u - v$, product uv , quotient u/v and composite $u \circ v$ (where $(u \circ v)(x) = u(v(x))$). This gives us four different stages which become progressively more sophisticated.

1. *Procedure*: Carried out by a single step-by-step sequence of actions.
2. *Multi-procedure*: Several different procedures are available that give the same result.
3. *Process*: A function with given input–output relationship.
4. *Procept*: Where functions act dually as a process that can be carried out by various procedures or as mental objects that can be operated upon.

As the meaning shifts from one stage to the next, the mathematical techniques become more efficient, more flexible, and more interconnected to allow richer forms of mathematical thinking (see Figure 1).

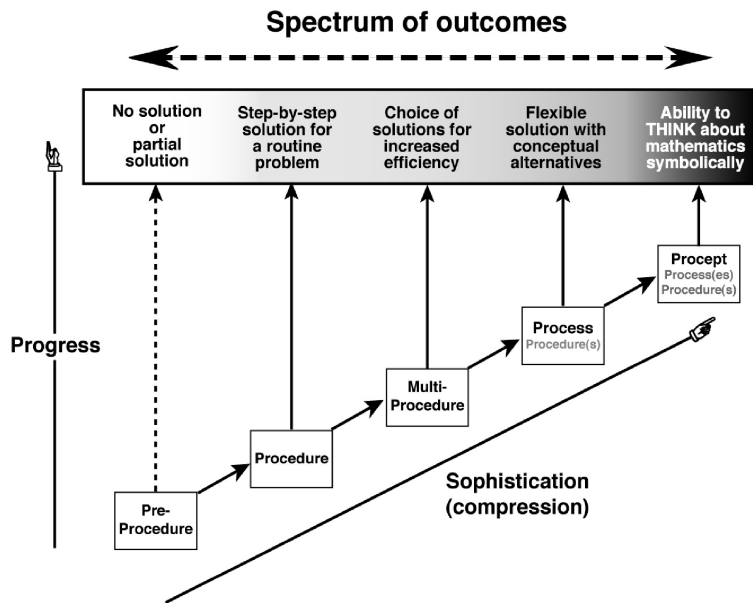


Figure 1: Spectrum of outcomes as symbolic compression becomes more sophisticated (expanded from Gray, Pitta, Pinto and Tall, 1991, p.121).

For example, the factorisation of the quadratic to solve the equation $ax^2 + bx + c = 0$, can be performed by three related procedures: factorising the quadratic, completing the

square, or using the quadratic formula (which is derived from completing the square). A group of Brazilian teachers, conscious of their students growing difficulty with algebra and the need for them to gain success on tests, decided to focus mainly on the quadratic formula which could essentially be used to solve any quadratic. Their students were asked to respond to the following:

To solve the equation $(x - 2)(x - 3) = 0$, John answered in one line ‘ $x = 3$ or $x = 2$ ’. Is the answer correct? Analyse and comment on it (Lima and Tall, 2006).

Only six out of seventy-seven students gave a satisfactory answer. Three substituted the values into the equation, and of the remainder, the most common response, begun by sixteen students was to solve the equation from scratch. Fourteen attempted to multiply out the brackets, six, of whom four then used the quadratic formula, did it correctly, and just three found the correct roots. No student mentioned the idea that ‘if the product of two numbers is zero, then one of them must be zero’. Using the analysis in Figure 1, these students remained at the level of a single procedure, lacking the efficiency of having different procedures appropriate for particular contexts and the flexibility to think about mathematics symbolically.

As another example, the following calculus problem can be solved in several different ways

$$\frac{d}{dx} \left(\frac{x^2 + 1}{x} \right).$$

One is to write $u = x^2 + 1$, $v = x$ and to use the quotient rule, which leads to an expression that requires several steps to simplify it. Another is to rewrite the formula as $x + x^{-1}$, which can be differentiated term-by-term in a single step to give $1 - x^{-2}$. Another, more complex way is to write

$$y = \frac{x^2 + 1}{x},$$

so

$$xy = x^2 + 1,$$

and to differentiate xy as a product to obtain

$$x \frac{dy}{dx} + y = 2x,$$

which, after some simplification, gives the required derivative. This is less efficient than either of the other methods, but gives yet another procedure to carry out the same process of differentiation.

When thirty-six Malaysian students taking a calculus course taught mainly by procedural methods were asked how many solutions they could give to this problem, the twelve most successful students with grade A on the previous year’s examinations could offer significantly more procedures than the twelve who achieved grade C. (Ali and Tall, 1996) (see Table 2). This shows greater flexibility associated with higher examination grades.

Student Grade	0 or 1 methods [procedure]	2 or 3 methods [multi-procedure] [or process]
A	3	9
B	7	5
C	9	3
Total	19	17

Table 2: Flexibility of student solution processes.

Procedural and conceptual thinking

The two examples given so far are both solvable by procedural responses. The fluent and efficient use of procedures is part of the development of mathematical fluency, but it is not enough. Procedures *occur in time* and it is difficult to think about other things at the same time as carrying out a procedure. What has been noticed with some alarm is that there is a growing tendency for students to be able to solve 1-step problems requiring a single procedure, but a loss of ability in solving multi-step problems (London Mathematical Society, 1995). Teaching procedures is *part* of the whole development, but is not sufficient for long-term development of mathematical sophistication. To reach the higher levels of flexible operation requires the making of connections and I conjecture that making connections is easier when procedures are compressed into thinkable concepts after the manner indicated by Thurston. This involves a steady compression of meaning in the symbolism, and can also be seen by representing the concepts in other ways.

Embodiment and symbolism

Mathematical concepts can be represented as physical actions (such as a transformation), as models, pictures, words and symbols. Bruner (1966) described three different modes of operation.

What does it mean to translate experience into a model of the world. Let me suggest there are probably three ways in which human beings accomplish this feat. The first is through action. [...] There is a second system of representation that depends upon visual or other sensory organisation and upon the use of summarising images. [...] We have come to talk about the first form of representation as **enactive**, the second is **iconic**. [...] Finally, there is a representation in words or language. Its hallmark is that it is **symbolic** in nature (Bruner, 1966, pp. 10–11).

The enactive mode through action and gesture is of particular value in mathematics. For instance, we may enact the gradient of a graph by moving our hand along it to sense where it slopes up, where it is horizontal and where it slopes down (see Figure 2).

I term the combination of enactive and iconic, together with the mental thought experiments that accompany them, the *embodied* world of mathematical thinking. It

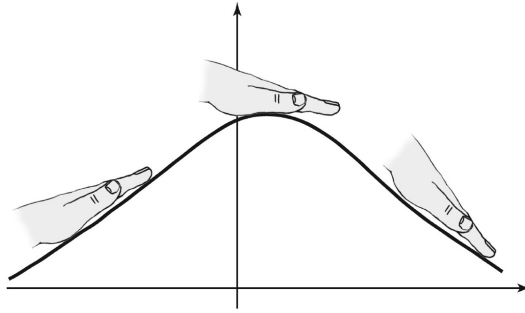


Figure 2: Dynamically tracing the changing gradient of a curve with the hand.

complements the symbolic world of calculation and manipulation in arithmetic, algebra, symbolic calculus and so on. For further details, see, for example, Tall 2004, Tall, 2006.¹

An example: The derivative of $\cos x$

Figure 3 shows the graph of $\cos x$ and the practical gradient function which stabilises to look like the graph of $-\sin x$ (using Blokland, Giessen and Tall, 2000). In this way it is possible to *see* the gradient function *before* the need to compute it symbolically.

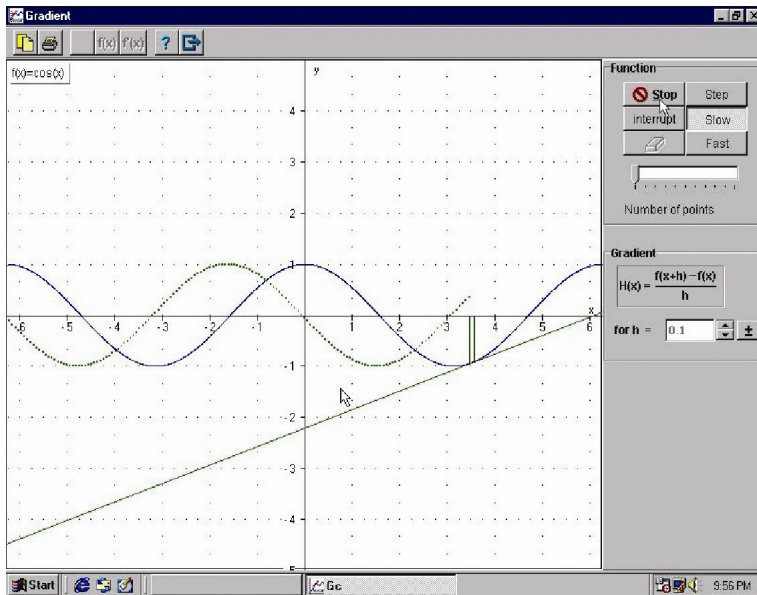


Figure 3: The gradient of $\cos x$ looks like $\sin x$ upside down.

¹Obtainable from the author's website at www.davidtall.com/papers

What is important here, is that the student makes conceptual links and expects the derivative of $\cos x$ to be $-\sin x$, rather than needing to use the limiting process to prove the limit exists.

An example: The case of vector

The concept of vector arises in many guises: as a displacement, a velocity, an acceleration, a force, expressed visually as arrows of given magnitude and direction or symbolically in terms of column vectors and matrices. Students can be taught *procedurally* to add two vectors together as arrows representing given magnitude and direction by following one after the other and using the triangle or parallelogram law. But this does not necessarily carry with it a conceptual meaning. An embodied meaning may be given through considering a vector as a translation of a shape in space, say by translating a triangle on a horizontal plane (see Figure 4).

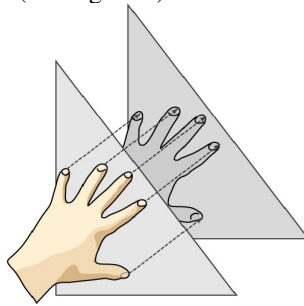


Figure 4: Translating an object.

The effect of the translation can be seen by the relative shift of any point on the triangle, or on the hand that moves it, represented by an arrow from starting point to finishing point. One may regard all these arrows as 'equivalent' with the same magnitude and direction. A more powerful alternative is to imagine a *single arrow* of given magnitude and direction that can be shifted to start at any point whose end-point then gives the finishing point. This gives the notion of *free vector*. Addition of free vectors is then accomplished by placing one after the other to obtain the unique free vector that has *the same effect* as the two free vectors traced sequentially (see Figure 5).

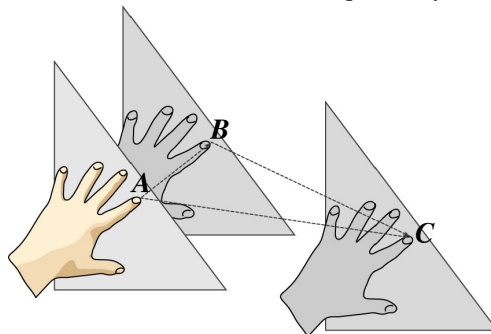


Figure 5: The sum of two vectors as the total effect of two translations.

If students conceive vectors as actual *journeys*, they may add them naïvely by doing one journey after the other, jumping in the middle as necessary, rather than the mathematical addition as free vectors (see Figure 6).

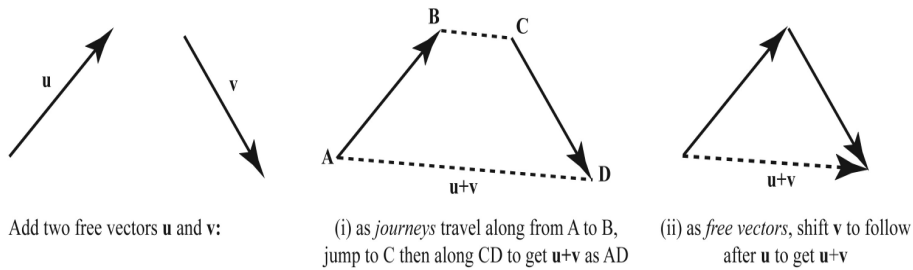


Figure 6: Adding vectors together.

The error of adding vectors as journeys arises through seeing them as actions, rather than as free vectors conceived as the effect of the actions. Taking this embodied approach to teaching vectors, focusing on the effect of a transformation, Poynter (2004) was able to significantly improve students' understanding of the mathematical notion of free vector.

Linking embodiment and symbolism

Mathematical symbolism arises from embodied actions such as counting, sharing, ordering, measuring, and so on. In this way, embodiment can give initial meaning and equivalence of symbols can be seen as actions *having the same effect*. For instance, equivalence of fractions (see Figure 7).

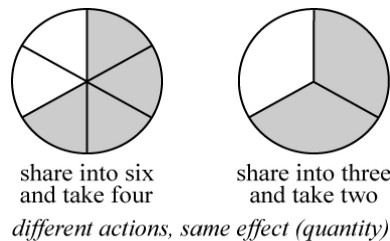
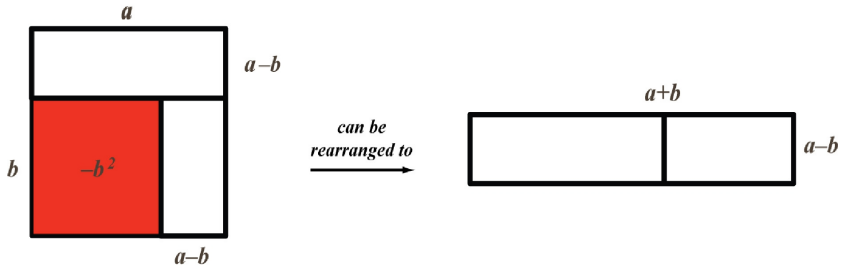
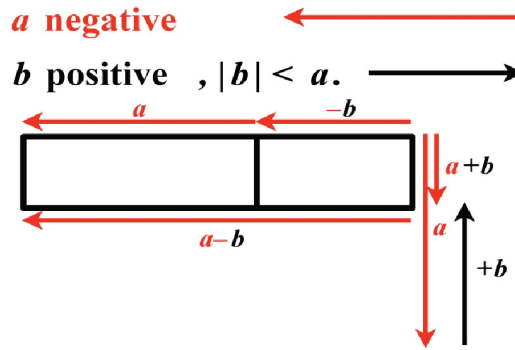


Figure 7: Equivalence in terms of actions with the same effect.

If the results of the actions are seen as objects, then picking up the four sixths and placing them over the two thirds shows that they are the same (in terms of quantity, if not in terms of the number of pieces). Algebraic identities such as $a^2 - b^2 = (a-b)(a+b)$ can be given an embodied meaning as shown in Figure 8.

Figure 8: $a^2 - b^2 = (a - b)(a + b)$.

This embodiment is straightforward when a and b are positive and $a > b$. But it soon gets complicated when $b > a$ or when the values a and b are positive or negative. This requires meaning given to negative lengths (by reversal) and negative areas (by turning over). Figure 9 shows the picture when $a < 0$, $b > 0$ and $|b| < a$. Can you see its meaning?

Figure 9: $a^2 - b^2 = (a - b)(a + b)$ for $a < 0$, $b > 0$, $b < |a|$.

Matters become even more complicated with the embodiment of formulae for higher powers:

$$\begin{aligned} a^3 - b^3 &= (a - b)(a^2 + ab + b^2) \\ a^4 - b^4 &= (a - b)(a + b)(a^2 + b^2). \end{aligned}$$

The former can be 'seen' in three dimensions, but the embodiment of the latter in four dimensions is far more sophisticated for mortals living in three-dimensional space. The situation becomes far more complicated when a and b have a mixture of positive and negative signs. Fortunately the symbolic manipulation is the same in all cases. For instance, the difference of two fourth powers is no more than the difference of the squares of a^2 and b^2 that can be handled in two easy stages:

$$\begin{aligned} a^4 - b^4 &= (a^2 - b^2)(a^2 + b^2) \\ &= (a - b)(a + b)(a^2 + b^2). \end{aligned}$$

As mathematics gets more sophisticated, the power of symbolism carries the successful mathematical thinker further. However, to do this requires not only meaning through linking symbolism to embodiment, but also meaning *within symbolism itself*. I suggest that such meaning occurs through switching focus from the steps of a procedure to its effect and the flexible use of symbols as procepts to give sophisticated meaning to symbol manipulation.

Making connections in the classroom

The teaching and learning of mathematics may be approached in a range of possible ways related to what is learnt, how it is learnt, and the responsibilities of the teachers and learners to themselves and to others. In a traditional *transmission* approach, the teacher provides a class of learners with an introductory explanation, followed by graded exercises for them to work on their own to build up specified concepts in an organised sequence. On the other hand, in a student-centred classroom the learners are seen as the architects of their own learning by *discovery*, with the teacher as a facilitator and organiser of resources. A more sophisticated approach is a *connectionist* classroom, in which the teacher as mentor orchestrates classroom activities, encouraging the learners to make connections by focusing on essential ideas, working in groups, sharing ideas and being challenged by problems. To categorise individual teachers in a study of the effective teaching of numeracy, Askew, Brown, Rhodes, Johnson and William (1997) designed a battery of phrases of the type given in Table 3. (The ones in the figure are modified slightly and I take responsibility for this.) The brief phrases only tell part of the story, though taken as a whole they reveal broad trends. As you look down the list to see which items you tend to agree with personally, you may find yourself choosing some items from one column and other items from others. To test myself, I decided to consider each line of three choices in turn and award a maximum of 3 points to the line in total, dividing the points according to my strength of feeling. I might give all 3 points to a single preference, or 2 points to a strong preference and 1 point to a weaker preference, or use just two points to give one each to two statements that I preferred equally over the third. My own scores were transmission 4, connectionist 12, discovery 4, showing a strong agreement with many of the connectionist items in the table, and with some agreement with elements of transmission and discovery.

Teacher's beliefs		
Transmission	Connectionist	Discovery
About pupils <i>being numerate</i>		
Primarily the ability to perform calculations by standard procedures.	Calculation methods which are both efficient and effective.	Finding the answer to a calculation by any method.
Heavy reliance on paper and pencil methods.	Confidence and ability in mental methods.	Heavy reliance on practical methods.
How pupils <i>learn</i> to become 'numerate'		
Individual activity based on following instructions.	Interpersonal activity through interaction with others.	Individual activity based on actions on objects.
Pupils vary in their <i>ability</i> to become numerate.	<i>Most</i> pupils are able to become numerate.	Pupils vary in the <i>rate</i> at which their numeracy develops.
Pupils learn through being introduced to one mathematical routine at a time and remembering it.	Pupils learn through being challenged and struggling to overcome difficulties.	Pupils need to be 'ready' before they can learn certain mathematical ideas.
How to <i>teach</i> pupils to become 'numerate'		
Teaching has priority over learning.	Teaching and learning are complementary.	Learning has priority over teaching.
Teaching is based on <i>verbal explanation</i> so that pupils understand the teacher's methods.	Teaching is based on <i>dialogue</i> between teacher and pupils to explore understandings.	Teaching is based on <i>practical activities</i> to enable pupils to discover methods for themselves.
Application is best approached through 'word problems'.	Application is best approached through challenges that need to be reasoned about.	Application is best approached through using practical equipment.

Table 3: Teacher orientation towards numeracy (selected from Askew, Brown, Rhodes, Johnson and William (1997)).

In the original research, teachers were classified using these categories and the improvements of their students were traced over a period as measured using National Curriculum tests and classified as highly effective, effective or moderately effective. (See Table 4, selected from Askew, Brown, Rhodes, Johnson and William, 1997, pp. 31–32). The data showed that those who were strongly connectionist were all highly effective. Those who were strongly transmission or discovery oriented were only moderately effective, while those with no strong orientation were in a spectrum between the two extremes, with the majority being effective rather than highly or moderately effective.

	Highly Effective	Effective	Moderately Effective
Strongly Transmission			Beth Cath Elizabeth
Strongly Connectionist	Anne Alan Barbara Carole Faith		
Strongly Discovery			Brian David
No Strong Orientation	Alice	Danielle Dorothy Eva Fay	Erica

Table 4: The relation between teacher orientation and effectiveness.

Discussion

Even though the data from the previous section relates to a single study focusing on numeracy, its potential implications are clear. The teacher who acts as a mentor, balancing the act of teaching and learning to encourage students to make connections is likely to be more effective. In many curricula, the emphasis is on giving meaning by relating the mathematics to real-world problems, suggesting the need to link symbolism to human embodiment. Embodiment works fine initially with simple cases but we have seen it may grow more complicated as the context becomes more sophisticated. Hence it is necessary to seek sense not only in embodiment but also within symbolism itself. Here the symbolic procedures need to be conceived in ways that are easy for the human brain to comprehend. I suggest that this involves compression of knowledge, switching the focus of attention from step-by-step procedures, not just to more efficient step-by-step procedures, but to the *effect* of those procedures. By doing this we see equivalent procedures having the same effect as representing one and the same *process* which can then be manipulated symbolically as a thinkable *concept*, giving a flexible *procept*. In whole number arithmetic, increased power arises from decomposing and recomposing numbers as procepts to give flexibility in arithmetic operations. In fractional arithmetic,

increased power comes from shifting focus from fractions such as $2/3$ and $4/6$ as different sharing procedures to processes representing one and the same rational number. In algebra, different procedures of evaluation—such as $(x - 1)(x + 1)$ and $x^2 - 1$ —having the same effect can be conceived as a single *process* that becomes a manipulable *concept* as a function. The shift from *action* to *effect* and on to *thinkable concept* occurs both in embodiment and symbolism. It gives the underlying mechanism to shift attention from routine procedures to build increasingly sophisticated mathematical thinking. Some students remain with procedures that become increasingly complicated to use. Others are more successful at developing more flexible thinking. There is a major role for teachers to act as mentors encouraging a greater number of students to compress knowledge into thinkable concepts that are appropriate for connecting ideas together in sophisticated and simple ways.

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A scientific approach to the teaching of the sciences: What do we know about how students learn in the sciences and how can we make our teaching match this to maximise performance?

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Abstract

If learning situations are designed in line with a scientific approach to teaching in mind then learning can be highly efficient and effective. If learning situations are not consistent with the way students learn, then problems can be expected. The curriculum revolutions of the 1960s, quite inadvertently, had brought about such inconsistencies. Students found many areas of physics and chemistry along with some parts of biology difficult. Many students were losing confidence and many countries reported a drop off in numbers electing to choose these subjects. In most parts of the world, the situation has not changed much since that time! The research work of the 1990s started to refine the model of learning and to use it to predict how improvements could be made. In several major studies, these predictions were applied to lecture-type learning, laboratory learning, to problem solving, and to curriculum construction and presentation. The results have been quite remarkable, with quite dramatic improvements in performance being reported along with some amazing changes in student attitudes. This paper seeks to summarise some of these results and to show how great improvements in learning (defined in terms of understanding) can be achieved simply by changing teaching approaches in line with the predictions from the model. This has been applied successfully in countries in the West, the Middle East and South-East Asia.

Introduction

In the early 1960s, there was a revolution in science education, with numerous curriculum revisions in many countries for school courses, especially in chemistry and physics (see, for example, Johnstone, 2000). In Scotland, the curriculum for secondary schools in chemistry and physics were radically altered (Scottish Examination Board, 1962a, 1962b) and the emphasis was on modernising the syllabus as well as placing a clear emphasis on guided inquiry with the students being expected to understand and apply ideas and not merely memorise them. Biology and mathematics soon followed. The outcomes were very positive, with the sciences and mathematics being very popular with school students. Indeed, even today, the university entrance examinations (known, in Scotland, as Higher Grades) show the consistent popularity of all these four

subjects, no other subjects (except English, which is a mandatory course in Scotland) coming near them in the numbers uptake (see Figure 1).

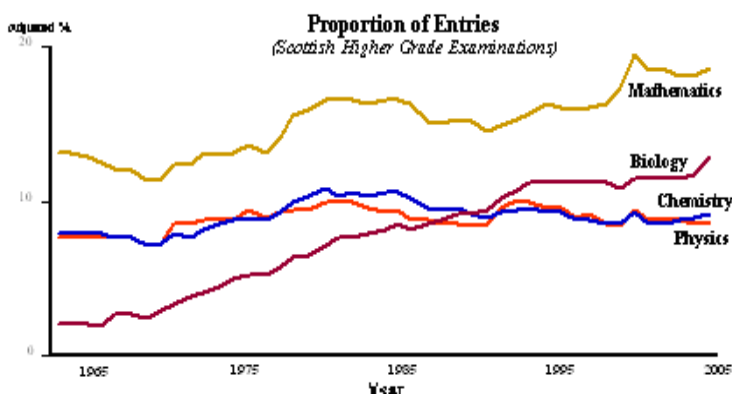


Figure 1: Proportions of entries in Scottish Higher Grade (Source: Scottish Qualifications Authority, 1995, 2006).

Difficulties

Despite all this, by the mid-1960s, reports were emerging in Scotland (and in other countries where parallel changes had occurred) that students found the new syllabuses difficult. To be more accurate, they found some parts of the curriculum difficult. The first thing was to find out which parts and then to explore the reasons as to why. In a major study published in 1971, Johnstone, Morrison and Sharp (1971) gave a good picture of which areas caused most problems in upper school chemistry, and these are summarised.

- Redox (e.g. E°) and ion electron ideas.
- Topics with some arithmetical content, e.g., thermochemistry and thermodynamics.
- Organic topics like esters, proteins, amines and carbonyls, aromaticity.
- Topics related to equations and the mole, e.g., volumetric and gravimetric work, Avogadro and the mole.

Later studies found the major difficulties in physics, these being summarised by Zapiti (2001) and by Chen (2004). Chen identified acceleration and velocity; connecting momentum and kinetic energy; electric potential difference and current; representing electrical circuits; electrical resistance; reflection and refraction; heat and temperature, as the most important at early stages. For biology, there turned out to be only two areas where students reported consistent problems: water transport phenomena and genetics

(Johnstone and Mahmond, 1980) although a later study revealed that only genetics remained as a problem area in Scotland (Bahar, Johnstone and Hansell, 1999). Over many years, many studies were carried out to explore these areas of difficulty. However, the key thing was to find out why certain topics caused problems. Was it intrinsic to the nature of the sciences or was it related to the way humans learn in highly conceptual areas? It turned out to be both (see Johnstone, 1997, 1999, 2000). Although these papers relate specifically to chemistry, parallel work has shown that physics and biology are similar (see Chen (2004) for physics, and Chu (2007) for biology specifically while Johnstone (1991) offers an excellent overview).

Two other important findings occurred at about the same time. The first one was the finding by Miller (1956) that the capacity of part of the brain could be easily measured. This part is now known as the working memory and it is that part of the brain where we do our thinking, understanding and problem solving. Not only could its size be measured but it was found to grow with age (up to age sixteen), was genetically fixed and was a rate-determining step in much learning (Baddeley, 2000). The average adult capacity is seven and most adults possess a capacity between six and eight. The breakthrough came when Kellett (Johnstone and Kellett, 1980) observed that all the topics causing difficulty were those where there was a high information load on the learner. Information load was defined as the number of pieces of information which the learner had to hold at the same time in order to perform the task successfully. Could it be that the limited capacity working memory was being overloaded with the topics which were proving difficult and that this was the source of the problem? One paper brought the ideas together in a clear way (Johnstone, 1991).

Working memory

A series of major experiments measured the working memory capacity of large numbers of students (at school and university) and related the working memory capacity to performance in a large number of questions whose information load has been assessed. Almost invariably, working memory capacity correlates positively (ranging from 0.2 to 0.6) with performance (see Table 1).

However, the relationships between working and performance is not a simple one. It was found that the relationship was not linear. When a task exceeds the working memory capacity, performance collapses quite spectacularly (Johnstone and El-Banna, 1986, 1989). Figure 2 shows the kinds of graphs which are frequently obtained.

However, further analysis gave an even more interesting picture (see Figure 3). The sample in one experiment (Johnstone and El-Banna, 1986, 1989) was divided into three groups by their measured working memory capacity. The point of collapse in performance corresponded approximately to one unit less than their measured working memory capacity.

The results of the experiment seem to be highly reproducible and particularly marked for mathematics (Christou, 2001) but have been shown to occur in almost all school subjects as well as some university subjects like chemistry. However, it is possible to remove the effect completely, simply by making sure that all questions asked do not overload the working memory (Reid, 2002). This is nothing to do with trivialising the test questions and making them easy. In this specific case, the test was not easy and

Subject	Country	Age	Pearson Correlation
Chemistry	Greece	15	0.34
Mathematics	Greece	16	0.40
Mathematics	Kuwait	13	0.52
Physics	Taiwan	13	0.30
Statistics	Malaysia	19	0.12
Biology	Taiwan	13	0.25
Computing	Scotland	19	0.16
Social Science	Kuwait	13	0.19
Islamic Studies	Kuwait	13	0.16
Mathematics	Kuwait	13	0.19
Science	Kuwait	13	0.20
English	Kuwait	13	0.16
Arabic	Kuwait	13	0.19
<i>Total of six</i>	Kuwait	13	0.22

Table 1: Working memory correlations with performance.

the marks were not good. Nonetheless, the performance did not relate to the working memory capacity of the students simply because of the way the questions were asked.

In passing, if working memory capacity is related to performance in examinations, then it might be seen as a mark of intelligence. Thus, a person with an above average working memory capacity is perhaps more intelligent. While it is true that working memory capacity measurements do correlate with the results from intelligence tests, the assumption that working memory is an aspect of intelligence needs questioning. Firstly, there is no agreed definition of intelligence and it tends to be equated with the performance in an intelligence test. An intelligence test is rather like any school test but the subject matter is not critical: it is like a content-free school test. It is little wonder that intelligence tests correlate with school and university performance. The whole thing is a circular argument!

The working memory capacity determines aspects of the way a person processes information. It is perfectly possible for a person to work within a small working memory by using appropriate strategies and this has been shown specifically for field dependency (see, e.g., Danili and Reid, 2004a).

A way forward

These experiments give a clear way forward in making the science subjects more accessible to learners. If neither the way of presentation nor the way of assessment require the learner to hold more information than the capacity of their working memory, then their performance will relate to their knowledge and skill in the subject and not to their working memory capacity. However, it was not quite so simple. The working memory is the place where each person mentally works; it is here that information is held temporarily, the information is worked on, rearranged, brought together, understood.

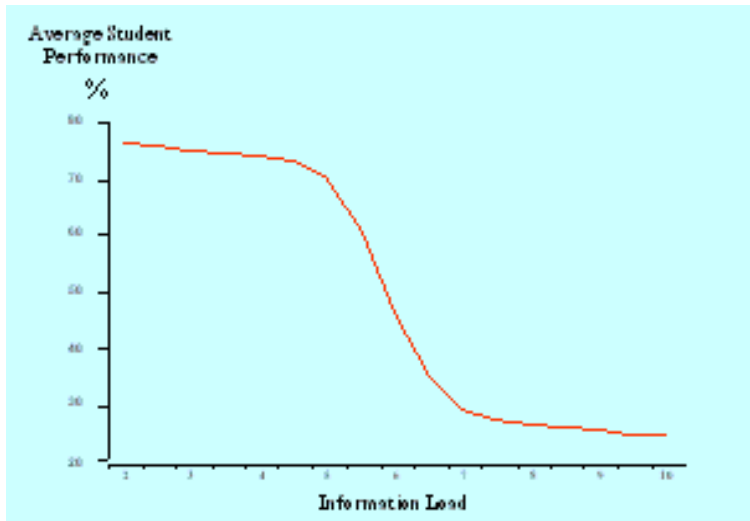


Figure 2: Performance collapse as information load increases.

Extra information is drawn from long term memory and thinking and problem solving take place. It is now known that the capacity has to accommodate not only the items of information to be held at the same time but also to have space to carry out the necessary processing of that information (Johnstone, 1997). The evidence from these experiments and much other work started to lead to a model of learning which is now widely accepted in much educational psychology. This is shown in Figure 3.

There are some very straightforward predictions from the model.

- If working memory is overloaded, learning will more or less cease.
- If the perception filter works efficiently, overload is less likely.
- The filtration is controlled by what you know already.
- If knowledge is stored in linked fashion, it will be more easily recalled.

The effect of overloading the working memory has been demonstrated again and again. The effect of the selection of information by means of the perception filter can also be shown easily. Part of the process is known as field dependency. In simple terms, different people have different abilities to select what is important for a particular task from all the information which is presented. Those who are good at the task are known as field independent. This work has developed from early work by Witkin (Witkin and Goodenough, 1981): he developed a simple test known as the hidden figure test and this can be used to make a measure of this ability. When large groups of students are assessed for their field dependency, it is found that the results almost always correlate with test performance in the sciences and mathematics (Danili and Reid, 2004b). Indeed, some very recent work has shown that it correlates with test performance in most

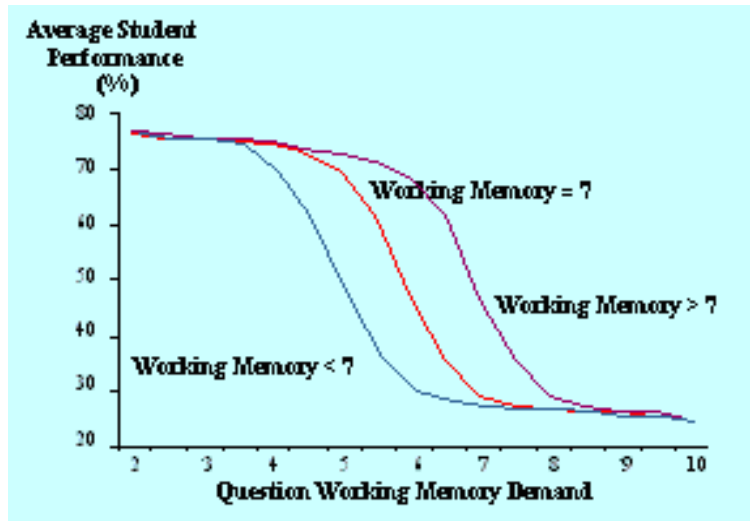


Figure 3: Performance collapse as information load increases.

subjects (Hindal, 2007). Typical correlations are shown in Table 2. The extent of correlation depends entirely on the type of test being employed and values seem to range from 0 to 0.5.

The key message from all the research is that learners all learn in essentially the same way. Information is selected from all that comes to the learner. It is held temporarily in the working memory and the learner attempts to understand or to solve the problem. It may then be stored in the long term memory, perhaps to be recalled later. Recent work (Reid and Yang, 2002) suggests very strongly that recall of information is highly dependent on the way it is stored. Some people store information in a visual form while others prefer a more symbolic approach. Some handle both well. The key thing is that it seems to be the presence of usable links between ‘nodes’ of knowledge which is the key (Al-Qasmi, 2006). Those who have stored the information in a highly-linked matrix of ideas can access the information later much more easily. Indeed, conceptual understanding is dependent on the way ideas are linked to each other in meaningful patterns.

Information processing and other models

There are many variants of the information processing model of learning in the literature (Atkinson and Shiffrin, 1971; Baddeley, 1990; Ashcraft, 1994; Johnstone, Sleet and Vianna, 1994). However, they all are essentially the same although they sometimes use different labels. In other words, all humans learn in essentially the same way. Through our senses, we take in information from our environment, we select what is of importance and relevance to us at a particular moment, we process it in some way and then, perhaps, we store what we have found. The remarkable thing is that the model

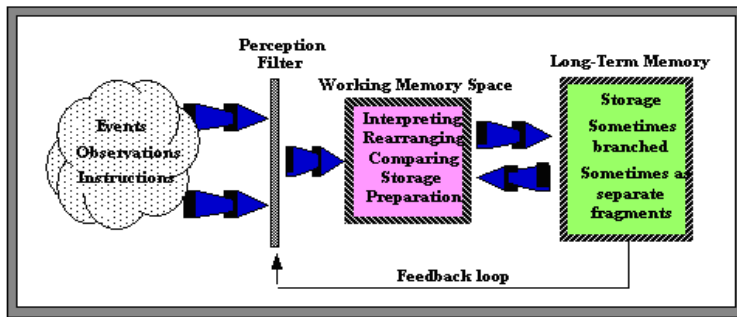


Figure 4: A model of information processing (after Johnstone, 1997).

absorbs and often explains observations for other insights and models. For example, the observations of Piaget about the development of learning with age in the child can be related to language acquisition and the capacity of the working memory as it develops with age (Johnstone, Hogg, MacGuire and Raja, 1997; Johnstone and Selepeng, 2001). The working memory grows by one unit for every two years of life, very approximately.

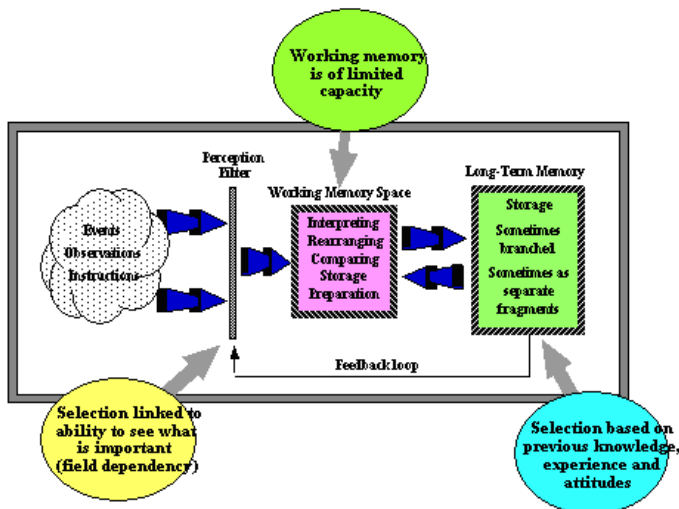


Figure 5: Implications from information processing.

The work of Ausubel (1968), with his very helpful insights into meaningful learning, is interpreted in terms of the way knowledge is stored in long term memory. The more knowledge is understood and stored meaningfully, the more links are created between ideas and concepts. Recent evidence has offered some fascinating preliminary

Subject	Country	Age	Pearson Correlation
Multiple Choice	Greece	16	0.21
Short Answer	Greece	16	0.33
Structural	Greece	16	0.25
Communication Grids			
Social Studies	Kuwait	13	0.12
Islamic Studies	Kuwait	13	0.08
Mathematics	Kuwait	13	0.21
Science	Kuwait	13	0.19
English	Kuwait	13	0.19
Arabic	Kuwait	13	0.18
<i>Total of six</i>	Kuwait	13	0.20
Mathematics	Greece	16	0.50
Chemistry	Scotland	16–18	0.13–0.24
Biology	Scotland	17	0.27

Table 2: Field dependency and examination performance.

insights into the importance of these links (Al-Qasmi, 2006). Ausubel also stressed strongly the importance of prior knowledge and experience in controlling future learning and this is seen as the feedback loop where the knowledge in the long term memory influences the perception filter.

Even constructivism is interpreted and explained as a natural process. The learner is trying to make sense of what is being offered. If the new knowledge is stored and linked correctly to previous knowledge which is itself correctly linked up, then we have meaningful learning. If new knowledge is linked incorrectly, then we have the start of misconceptions or, perhaps, alternative conceptions. If knowledge is stored unlinked, then we have rote learning. Indeed, writing from a cognitive load perspective, Kirschner, Sweller and Clark (2006) raise very serious doubts about the whole enterprise of ‘constructivism’ as a predictive tool ‘The cognitive description of learning is accurate but the instructional consequences suggested by constructivism do not necessarily follow’ (p. 78). The fundamental problem is that such approaches have not taken into account the rate determining control of working memory on all understanding and problem solving. This is a major weakness of constructivism and many other models.

The human being seeks to understand, to make sense of things, to create a meaningful whole. This is the natural process of learning. Too often, we force our students at all levels to memorise. Humans can be quite good at this but it is very different from meaningful learning and lacks the intrinsic satisfaction which is created when we make sense of some idea. This tends to generate very negative attitudes towards learning and towards the subjects being learnt. This shows in the unpopularity of chemistry and physics in many countries. The curricula and ways of teaching have meant that the working memories of learners are frequently overloaded and they have to resort to memorisation of facts in order to pass examinations. They choose to opt out whenever

possible.

In a very recent study, a deliberate attempt was made to present the material (which was not changed) in ways which avoided working memory overload. Not only did performance rise quite dramatically, but the attitude change was so great that a population negatively disposed to chemistry suddenly started to express very strongly positive views about chemistry (Hussein, 2006). This will be discussed later.

The idea of pre-learning

There are several very simple predictions which the model offers. It is known that, if the working memory is overloaded, then meaningful learning more or less ceases (Johnstone, 1997). Overload can be reduced if the perception filter selects more efficiently. Thus it is controlled by what is already known and stored in long term memory. This led to the idea of pre-learning.

In a large university first-year chemistry class (size varied from 160 to 220 from year to year), students were given pre-learning experiences in the first two years, these being discontinued in the next three and then, finally, pre-learning was re-introduced in a paper form known as 'chemorganisers'¹ in the final year. The original pre-lectures took the form of a series of short activities based on previous knowledge and this was undertaken before each lecture course. When these were discontinued, the extra time was given over to the lectures. The key observation is that the experiences known as pre-learning had the greatest benefit for those in the class who were least well qualified in chemistry (the lower group).

The aim of pre-learning was to bring to the surface previous ideas so that these ideas then enabled the selection filter to work more efficiently. The new material then was more easily understood as the working memory was less likely to overload. The key thing to note is that the less well qualified group (lower group) did statistically as well as the better qualified group (upper group). This shows the power of pre-learning and has been confirmed by a number of experiments looking at laboratory learning. The full experiment is described in Sirhan and Reid (2001).

First-year general chemistry class					
Year	Pre-learning	Upper group average	Lower group average	Difference	Significance
1993-94	Pre-lectures	50.9	48.8	2.1	Not Sig.
1994-95	Pre-lectures	49.2	49.0	0.2	Not Sig.
1995-96	No pre-lectures	46.9	38.7	8.2	Sig.
1996-97	No pre-lectures	48.2	42.0	6.2	Sig.
1997-98	No pre-lectures	46.7	41.3	5.4	Sig.
1998-99	Chemorganisers	49.8	47.7	2.1	Not Sig.

Table 3: The effects of pre-learning.

Pre-learning has a very large effect in making laboratory learning much more ef-

¹These are available online on the Chemorganisers homepage at <http://www.gla.ac.uk/centres/scienceeducation/Chemorg/ChemorganisersHomePage>

fective. In one experiment in physics (Johnstone, Watt and Zaman, 1998), students undertook four experiments, two with pre-learning experiences and two without. The sample was a large first-year university class. Tests for understanding were applied afterwards and, on average, the performance in these rose by 11 per cent as a result of the pre-laboratory experiences. Another study was conducted in chemistry, with even larger numbers ($N > 500$) and, yet again, the power of pre-learning, as predicted, to improve understanding was very marked (Johnstone, Sleet and Vianna, 1994). There was an added bonus to the second experiment in that it was shown very clearly that open-ended experimental laboratories could be conducted and that pre-learning had a very large effect in enabling these to work well.

Such pre-learning is evident in many school classrooms where, by skilful use of questions and recapitulation, the class is reminded of previous learning which, in turn is then able to inform the perception filter. Working memory overload is less likely and subsequent understanding is enhanced. This offers a simple explanation of a practice which good teachers have used for generations.

Reducing working memory overload directly

Of course, re-organising teaching to reduce the overload on working memory directly is always possible. There are several examples of large experiments where this prediction has been tested and found to generate very marked improved performance in tests of understanding. Of course, it is easy to get better examination marks if we make the examinations easier. It is easy to get students to pass examinations if we trivialise what is to be taught. However, students soon see through such deception.

The prediction from the Information Processing Model is that, if we reduce the demand on the working memory, then learning (seen in terms of understanding) will improve. The content to be taught is not changed. The time allowed for learning is not changed. Difficult themes are not avoided. Re-training of teachers is not envisaged. What was done was to change the teaching order, modifying speed and sequencing, breaking down complex areas into smaller parts and allowing the learning to fit the human psychology outlined in the information processing model. This was achieved by thinking through each difficult theme and then making sure that it is presented in a step by step way, thus reducing the load on working memory.

The key thing to note is that working memory causes a problem when too much has to be thought about at the same time. By careful sequencing of ideas, by reminder and illustration, by a stepwise approach, the working memory is not faced with too much at the same time. It is predicted that learning will increase.

Danili (Danili and Reid, 2004a) re-designed a large section of chemistry teaching at school level, specifically to reduce working memory overload problems. She measured the working memory capacity of the students and also their ability to 'see the message from the noise' (field dependency).

Firstly, the outcomes she obtained were precisely as predicted (Danili and Reid, 2004a). Those with higher working memory capacities did better and those who were field independent (they could select efficiently) did better. The effect was statistically highly significant. This can be illustrated in Table 4 which shows the average performance (as a percentage) of nine subgroups, formed on the basis of their measured

working memory capacity and extent of field dependency. Note that in the table ‘wm’ stands for working memory.

N = 105	Field dependency		
	Dependent	«—»	Independent
wm $\leq$ 5	47%	54%	59%
wm = 6	46%	60%	72%
wm $\geq$ 7	58%	69%	78%

Table 4: Examination performance.

The average performance increases as working memory capacity increases while the average performance also increases as the pupils are more field independent. This makes complete sense in that working memory overload is less likely with a higher working memory capacity and those who can select the ‘message’ from the ‘noise’ are less likely to take in extra unnecessary information to their working memories, thus causing possible overloads. However, it is worth noting just what a big difference the two effects can make. Those with high working memory capacities and who are field independent scored, on average, seventy-eight per cent. Those with low working memory capacities and who are field dependent scored on average, forty-seven per cent. This is a large difference of thirty-one per cent and is typical of the effects observed in the sciences and mathematics (see later). Because the effect can be so large, it is important to avoid excessive demands on working memory and this is what Danili did next.

In this follow-up experiment, several areas of the school chemistry syllabus were re-organised. The aim was simply to reduce the load on working memory in the way the material was presented. Half the pupils (the total sample was 205) followed the approach in the traditional way while the other half used materials which had been modified to reduce working memory load. There were no changes to content, time allocations or teachers. The experimental group improved performance by twenty-two per cent, while the control group improved performance by only thirteen per cent (Danili and Reid, 2004a). The effect was statistically highly significant.

Danili’s work involved several small sections of a syllabus, with pupils aged between fifteen to sixteen. In a much larger experiment, with a total sample of 800, pupils in two year groups towards the end of their studies in school chemistry experienced being taught by new materials covering major sections of the school syllabus. The new materials were designed with several factors in mind: they aimed to minimise working memory overload, to use relevant applications, to encourage understanding and not memorising, and to link new material to previously taught material in a meaningful way. All of this was based on the Information Processing Model being discussed here. The experimental structure which was used is shown in Figures 6 and 7 (Hussein, 2006).

In this way, group 1 is the experimental group for the teaching on the periodic table while group 2 is the experimental group for the teaching on chemical equations. This experimental structure does not require exactly balanced groups and has the ethical

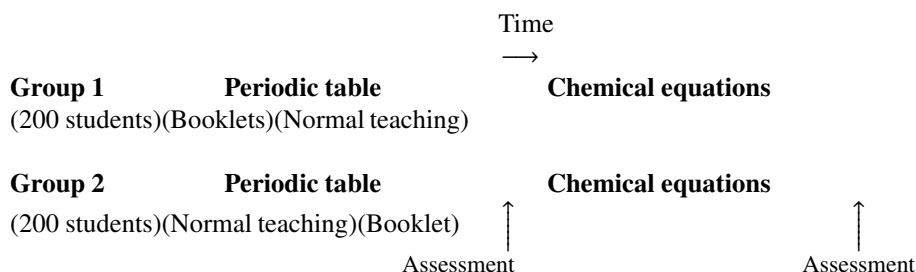


Table 5: Experimental plan – Year 10.

advantage that both groups are having the experience of the new materials in one topic. A similar experimental structure is used for year 11 (see Figure 7).

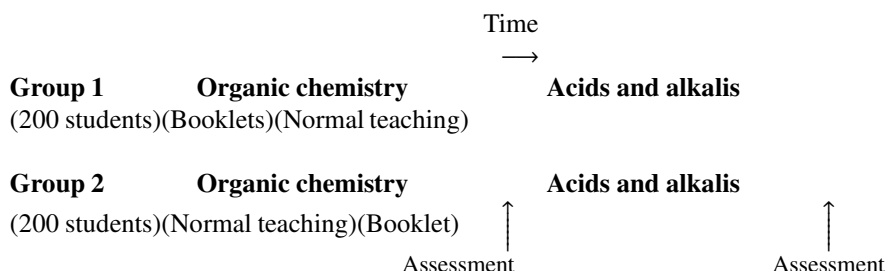


Table 6: Experimental plan – Year 11.

There is one other advantage. It allows the booklet experiment to be repeated, using two age groups, although involving different topics. The results which were obtained are shown in Table 5.

The remarkable thing is that, with large samples and large areas of the curriculum, the average performance rose for the four areas by an average of thirteen per cent. This is simply a huge change, completely transforming the examination performance of these pupils. This work was conducted in the Emirates and there was no contact at all with the many teachers involved. What was even more remarkable were the outcomes from the attitude measurements. It was shown that large negative attitudes toward most aspects of the school chemistry experience had been converted into strong positive perspectives. As with the examination performance, attitudes had been transformed simply by applying the ideas predicted from the Information Processing Model.

The evidence from these experiments in chemistry is that, by simply applying the predictions of the Information Processing Model, performance and attitudes can be enhanced enormously. A similar effect has just been report with genetics education with thirteen year old school pupils in Taiwan, but this awaits publication (Chu, 2007). Here, there was observed the same marked improvement in performance and also considerable changes in attitudes.

This can be summarised by looking again at the Information Processing Model.

N = 800	Mean (%)	Gain	<i>t</i> -test	Probability
Periodic table (Year 10)				
Experimental group	79.2	18.2	26.2	p < 0.001
Control group	61.0			
Chemical equations (Year 10)				
Experimental group	80.2	9.2	9.7	p < 0.001
Control group	71.0			
Organic (Year 11)				
Experimental group	71.0	14.0	19.7	p < 0.001
Control group	57.0			
Acids and alkalis (Year 11)				
Experimental group	75.0	10.7	15.1	p < 0.001
Control group	63.3			

Table 7: Improvement in performance.

There are three major components. If we arrange teaching and learning in line with the ways which allow each of these components to work efficiently and effectively, then we achieve better understanding. If there is better understanding, then attitudes become more positive (see, for example, Reid, 2006)

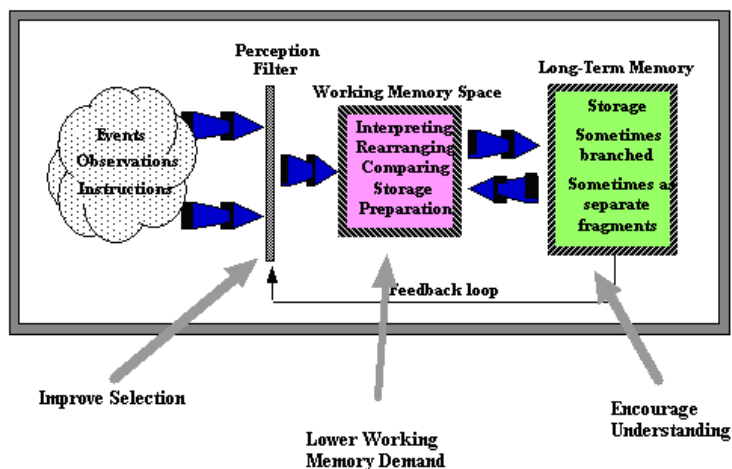


Figure 6: Three parts of information processing.

Understanding can be enhanced in the following ways:

- Selection can be improved by pre-learning.
- Lowering working memory demand can be achieved by changes in presentation.
- Understanding can be increased by deliberately linking new material to older material.

Conclusions

By virtue of the studies we all undertook in our science disciplines, in varying degrees, we can act scientifically in our own areas of specialisation. This paper argues that we can be just as scientific with regard to our teaching. Far too much curriculum construction, textbook writing and teaching approaches are based on assertion and opinion. No scientist ever works that way in their own scientific area. Science is developed on the basis of evidence and that evidence is mainly gained by means of carefully conducted experiments.

This paper has gathered the outcomes from many carefully conducted experiments carried out in many countries with learners of diverse ages and backgrounds. While there is enormous variation in the ways we all prefer to learn, the actual fundamental process of learning is the same for everyone. Through our senses, we take in information from our environment, we select what is of importance and relevance to us at a particular moment, we process it in some way and then, perhaps, we store what we have found.

Understanding must be the aim for all good education, irrespective of the discipline. There are key rate determining stages in achieving that understanding. Firstly, how well can the learner select what is essential for the task at hand? Secondly, how well can the working memory cope with the information coming in? And thirdly, how well can ideas be linked in long term memory to make a meaningful whole?

By taking the outcomes from the experiments described in the literature, it is possible to improve all of these markedly, with a vast improvement in the outcomes for the learners. This is seen not only in better examination results but also in the way much more positive attitudes are developed. In this way, as teachers, we have a great opportunity to excite our pupils and students so that they too can be stimulated to make sense of the physical and biological world, thus becoming more informed citizens and, perhaps even the scientists of the future.

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Contributed Papers

Mathematics

The effect of learning styles in learning mathematics with technology

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Abstract

This study investigates the effect of learning styles on students who are learning mathematics with technology. The result does not indicate that there is any statistically significant difference in performance among students with different learning styles. However, the results seem to show that students with certain learning styles may be predisposed to benefit more by learning mathematics using technology.

Introduction

Educators have long realised that people are different and have different ways of doing things. The preferences, tendencies, and strategies that individuals exhibit while learning constitute what have come to be called *learning styles* (Thomson and Mascazine, 1997). People have different learning styles, and studies have shown that if individual learning styles are accommodated in the teaching process, they result in an improvement in attitudes toward learning, in academic productivity, and in academic achievement (Griggs, 1991). Learning style is a source of strengths and weakness for an individual. If the presentation of a lesson coincides with a student's learning style, there is a tendency for the student to benefit tremendously from the lesson. Otherwise, this may negatively affect the learning process of the students. The knowledge of individual learning style is considered an important area for personal academic competence and crucial for the improvement of education (Kolb, 1984; Griggs, 1991). In a mathematics classroom, the knowledge of student learning styles has a dual advantage. First, it helps students to understand and become aware of how they learn, and the best way to study. Studies have shown that students who know their personal learning styles often do apply such information with great success and enthusiasm (Griggs, 1991). The second advantage of knowing a student's learning style is that the knowledge helps the teacher in the preparation of their teaching strategies, lessons, and classroom activities that will maximise the student learning process.

Literature review

Review of literature on the learning and understanding of mathematics reveals that numerous instruments have been developed over the last three decades to measure different types of learning styles. These instruments evolved from a variety of conceptual orientations (Thomson and Mascazine, 1997). However, Keefe (1987) identified the *affective*, *cognitive*, and *physiological* learning styles as three important factors embedded in the way individuals perceive, interact with, and respond to their learning environment. Curry (1987), in an attempt to provide a framework for the growing number and variety of conceptions of learning style theories, conceives of what Griggs (1991) called the 'onion model'. The so-called onion model consists of the four following dimensions: *Personality*, *Information processing*, *Social interaction*, and *Instructional preference dimensions*. For a review, see Griggs, 1991.

Although these models are similar in the sense that they all focus their attention on identifying and addressing individual differences in learning styles, there are important differences among the models. Griggs (1991) observed that 'some models stress accommodation of individual style preferences while others stress flexibility and adaptation' (sec. 3, para. 5), and, 'there is a range of quality among the assessment instruments that operationalise the various models and lack of a research base for some of the models' (sec. 3, para. 5).

Among the cognitive learning style instruments, Kolb's learning style instrument (LSI) has been characterised as the most popular and perhaps the most controversial, and the one that has stimulated the most academic discourse on the subject (Kinshuk, 1996). The learning style questionnaire (LSQ) developed by Honey and Mumford (1986) is an attempt to address the 'loopholes' in Kolb's LSI.

Many empirical studies have been carried out using one form of learning styles or the other in the teaching and learning of mathematics. The aim in many of these studies was to investigate the relationship between student learning styles and their achievements in mathematics. However, the results of these studies are inconclusive. While many studies indicate the existence of a significant relationship between student learning styles and their achievements in mathematics (see, for example, Raiszadeh, 1997; Ulubabova, 2003), many others are pointing to the contrary (see Aseeri, 2000; Briggs, 2003; Cezair, 2003; LaPrise, 2003).

Other researchers investigated the effect of learning styles in students' achievement when learning took place within a computer-aided learning environment. The results of these studies are also inconclusive (see, for instance, Jia, 1994; Russell, 1988; Parker, 1989). It is worth noting that though LSQ has been identified as the most suitable instrument for measuring learning style in the computer learning environment (Kinshuk, 1996), not much is known on the use of the instrument in the computer-aided learning mathematics environment. This paper is an attempt to shed some light in this direction.

Methodology

For this study an experiment was designed and data collected over the course of a semester. Two modes of learning were used for all the participants of this study during the experiment: the online and offline. The offline learning consisted of a normal

classroom lecture that was conducted in a more or less traditional manner. The on-line learning consisted of a weekly computer laboratory session, online discussion, and learning resources on the intra- and Internet available to students. WebCT was used as a delivery mode of the online part of this course, and MATLAB software as a problem-solving tool.

Participants

The participants of this study were fifty-nine randomly-selected students from the second pre-calculus course of the Prep Year Mathematics programme at King Fahd University of Petroleum and Minerals. These students were in the second semester of their one year intensive orientation programme in preparation for university study.

Instrument used

The Learning Styles Questionnaire (LSQ) by Honey and Mumford (1992) was used to measure student learning styles and has been claimed to be the most widely used diagnostic of its kind in the UK.¹ LSQ is designed to characterise four categories of people with different learning styles, which were named by the authors as: *Activist*, *Reflector*, *Pragmatist*, and *Theorist* (to be explained shortly).

Data collection

The LSQ was administered to the students in the first week of the experimental semester, and students were given enough time to fill in the questionnaire and return it. The second part of the data, comprising students' final grade in the course, were collected at the end of the semester. The software used were MINITAB and Microsoft Excel.

Results and discussion

The dominant learning style in this study was found to be *Reflectors* as shown in Table 1. They consisted of 44 per cent of the students. According to Honey and Mumford (1992), reflectors prefer to look before they leap. They stand back and view experiences from a number of different perspectives, collecting data and take time to work towards an appropriate conclusion. They study the situation thoroughly before taking any steps. They collect information about the new experience as well as the opinion of experts in that experience. They are slow in decision making: they would like to have the picture clear before they take a decision. They enjoy observing other people in action. The strength of people with this learning style lies in their thoughtfulness before reaching a conclusion, spending a reasonable amount of time in thoroughly evaluating a new experience, which usually results in sound opinion and decision. The weaknesses include slowness in decision making, and fear of failure, so they are over cautious and too careful about taking risks.

The second prevailing learning style among the participants in this study are the *Theorists* with 24 per cent. They are characterised as people who live in the world of ideas. They prefer to analyse, synthesize, and integrate new information into a systematic and logical theory. They are not happy until they get to the root of the problem and discover the principles behind it. They are objective in their approach. They synthesize facts and observations to reach a logical, structured conclusion. They rigidly reject

¹As reported at <http://www.peterhoney.co.uk>

subjective and ambiguous ideas and situations. They also do not go well with people who take decisions without theoretical underpinnings. The strengths of people with this learning style are that they are systematic, they enjoy research skills, and are objective thinkers. The weaknesses include a lack of ability to handle subjective or uncertain situations (Kinshuk, 1996),

The third dominant learning style are the *Pragmatists* with 19 per cent. Pragmatists, like theorists, are keen on ideas. Nevertheless, pragmatists are keener in putting these ideas into practice. They would like to try and experiment with the new ideas, techniques and theories to see if they work in practice. They are open-minded and welcome any ideas that will help them to execute their actions successfully. They look for new ideas and discover their applications. They are interested in discussions on how to address problems. Nevertheless, they tend to be impatient with open-ended discussion that does not lead to making practical decisions or the solving of a problem. The strengths of people with this learning style include the fact that they are practical and realistic in their actions. They know what they are looking for, and welcome any idea that will help them achieve it. Among their weaknesses are that they are less interested in experiences or ideas that have no practical applications. In addition, they tend to spend less time on searching or thinking.

The least dominant learning style found among the participants in this study are the *Activists* with only 13 per cent. Activists love novelty and tend to have an open-minded approach to learning. They involve themselves wholeheartedly and without bias in new experiences. They take risks through trying out things without planning. They look for and like anything new. However, as the novelty disappears, they look for new experiences. They use brainstorming techniques to solve problems, but easily get bored with repetitive activities. They are exciting, vital and gregarious. The strengths of this style are in their open mindedness, self-motivation and love for trying new experiences. Their weaknesses include taking action without proper planning and adequate preparation, and lack of patience to pursue things to their logical conclusion; they easily lose motivation and interest.

In terms of performance, Activists out-perform all other groups with a mean of 3.03 out of 4, followed by Reflectors (see Table 1). Pragmatists appeared to have the lowest mean. The performance of Activists is not surprising since they are characterised as open-minded, not sceptical, and involve themselves fully without bias in new experiences. These qualities tend to make them enthusiastic about anything new, and they are also happy to be occupied by immediate experiences (Honey and Mumford, 1992).

Prior experience (years)	N(%)	M	SD
Activists	8 (13)	3.03	0.43
Theorists	14 (24)	2.45	1.08
Pragmatists	11 (19)	2.30	1.41
Reflectors	26 (44)	2.53	1.09

Table 1: Means (M) and standard deviation (SD) for achievement by learning style.

In investigating the level of the significance the effect of different learning styles has on student achievements in mathematics we used an analysis of variance (ANOVA). However, no statistically significant difference was found ($F(3,55) = 0.75$, and $p = 0.53$) among the achievements of students categorised based on their learning styles. Here, our findings coincide with many other studies in the literature (Gawronski, 1972; Raviotta, 1988; Aseeri, 2000; Briggs, 2003; Cezair, 2003; LaPrise, 2003). Other studies have reported students learning styles to be significantly correlated with their achievements (Vondrell, 1987; Russell, 1988; Bauer, 1991; Al-Badr, 1993; Raiszadeh, 1997).

Conclusion

In this study we investigated the effect of learning styles, as measured by LSQ, on student performance in a pre-calculus algebra course that is supplemented with a computer laboratory programme. No statistically significant difference was found among students with different learning styles as defined by Honey and Mumford (1986; 1992) in their mathematics achievement. The result, however, appears to show that students with special attributes characterised in their learning styles may be pre-disposed to learn better in a technology-rich environment. For instance, it was found that Activists, who are characterised as people that like novelty and have an open minded approach to learning, out-performed all other groups.

Since learning styles describe the manner in which students receive and transform knowledge, specialised universities such as King Fahd University of Petroleum and Minerals, which is an engineering-orientated university, should endeavour to find out the learning styles of its most successful students within its various programmes. This will go a long way in counselling students or even in the admission process.

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College algebra: A course in need of improvement

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Abstract

The position of college algebra is well entrenched in US-based college curricula. It serves more students than any other credit bearing mathematics courses and it is a college gateway for a large percentage of students. Since it is a base course of quantitative literacy, it should improve by concentrating on elementary data analysis, functions and modelling. Use of technology and group projects should be included to enable students to gain confidence to face quantitative problems in other disciplines. The major challenges are large failure–pass–withdrawal rates, reduced numbers of students going on to calculus and receding student interest. This paper analyses the various steps taken from different parts of the world to improve the traditional way of teaching college algebra and suggests major characteristics of an improved college algebra programme.

Introduction

The pragmatic reason that students take college algebra is to fulfill requirements. For many universities a course in college algebra is a general education requirement (Small, 2002). Though the particular skills taught in the courses are not often used in any other subsequent courses, college algebra is a programme requirement for disciplines like social and biological sciences. Typically, students view the content of traditional college algebra as irrelevant and the course itself as a tedious and incomprehensible barrier to obtaining a college education. The use of technology is slowly penetrating college algebra courses, but it could not make any material changes to the outcome (Beaudrie, 2001). If college algebra is to be a service course in terms of satisfying distribution requirements, then it must change to emphasize applications across the disciplines. If it is to be a mathematics appreciation course, then it must emphasize student involvement in problem solving and discovery.

Failure–pass–withdrawal rates

The percentage of students who receive a grade of F (failure) or D (pass) or who withdraw (W) from the course is unacceptably high. We have found the failure–pass–withdrawal (FDW) rates are between forty to sixty per cent. While many factors contribute to the current high FDW rates, lack of relevant content and teacher-centred

pedagogy have made traditional college algebra courses a barrier rather than a gateway. Several improved college algebra programmes have already succeeded in lowering FDW rates by fifteen to twenty-five per cent. Students in these programmes were drawn from the same pool and were subject to the same placement as students in the traditional sections but with different content and pedagogical focus (Small, 2002). In this paper we introduce a new outcomes-based approach which increases the overall effectiveness of such a course.

Outcome-based teaching

Outcome-based teaching (OBT), now widely understood as standards-based education, shifts from the traditional focus on what students should be taught (content) and the duration of teaching hours to a focus on setting universal standards of what students are expected to demonstrate. Outcome-based teaching requires the identification of what students will be able to do after instruction. The articulation of outcomes can be helpful for the teacher and student. Outcome-based assessment not only provides feedback on student achievement but on the effectiveness of instruction. According to the model of cognition for instruction (Rigby and Dark, 2001) the three interrelated factors are instruction (source of achievement), assessment (measuring scale) and outcomes (the achievement). Outcomes are the foundation of this triangular relationship. Putting theory into practice, the above model was used in a college algebra course. Outcomes were developed for the course, instruction was based on the outcomes, and assessments developed that were based on the outcomes. Table 1 shows all of the outcomes for the course while the third column explains the relative importance of each outcome. The academic committee consisting of experts from various departments finalised the relative importance of each outcome. The fourth column explains the weighted score of each outcome in various assessments while the fifth indicates the approximate number of hours allotted for each outcome.

For measuring these outcomes we conducted short tests, assignments, examinations and class projects. To increase the validity of the assessments, questions were developed based on the outcomes of the course. After the students took the examinations, a spreadsheet was created to record individual and group performance for each question. From this we analysed the achieved percentage of each outcome. We found that some of the outcomes were not achieved satisfactorily. We concentrated on those outcomes below the benchmark. Table 2 shows the outcomes, achieved percentage of outcomes for each student, outcome index and outcome score. Data for Table 2 was derived from the spreadsheet and the outcome index is the ratio of the number of students achieving the outcome to the total number of students. The outcome score is the score obtained by the product of outcome index and the outcome importance.

#	Outcomes	Outcome importance (1 to 5)	Weighted score (%) (Exams)	Number of hours (Total 45)
1	Simplify rational expressions and expressions containing absolute value.	3	6	3
2	Solve and graph linear, quadratic, polynomial, absolute value, radical and rational equations and inequalities.	5	12	5
3	Factor and solve non-quadratic expressions and equations using quadratic techniques.	5	12	5
4	Add, subtract, multiply, divide, and simplify complex numbers and solve equations involving complex numbers.	3	8	4
5	Graph functions including their translations, and state properties of graphs.	4	10	5
6	Perform function operations including the difference quotient, composition, and inverses.	4	10	5
7	Identify logarithms, manipulate and calculate them algebraically.	5	12	5
8	Solve real-world problems using exponential and logarithmic functions.	4	8	4

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#	Outcomes	Outcome importance (1 to 5)	Weighted score (%) (Exams)	Number of hours (Total 45)
9	Identify arithmetic and geometric sequences and series and calculate the sum of a sequence.	4	6	3
10	Apply these techniques to practical problems drawn from fields such as mathematics, business, and the social, life, and physical sciences.	5	16	6

Table 1: Representative outcomes for a typical college algebra course.

Outcome #	1	2	3	4	5	6	7	8	9	10	Outcome index	Outcome score
2	✓		✓		✓	✓		✓			0.5	2.5
3	✓				✓		✓	✓			0.4	2.0
5	✓			✓				✓			0.3	1.2
9	✓							✓			0.2	0.8

Table 2: Student achieved outcomes.

Remedial steps taken

The remedial steps taken to improve the outcome index are

- allotment of more teaching hours to the content related to the respective outcome;
- supplementary instruction for the weak students;
- counselling session by the coordinator or the head of the department;
- use of technology, for example, MyMatLab, MathLab, GraphCalc, Mapple, etc.; and
- classroom discussion, seminars and group projects.

We cannot assign a common remedial step for all outcomes. Depending on the content and the importance, we designed steps and the coordinator did a follow-up of the entire system. In the new system we found considerable improvement in accomplishing the outcomes.

There are two main theories of measuring outcomes after instruction; norm-referenced and criterion-referenced. Assessment to rank individual performance among students is

norm-referenced assessment which makes a comparison among students in situations like selection for entrance. But this type of assessment is not as useful for measuring the outcomes taught in the classroom. The appropriate assessment for this purpose is criterion-based assessment, which focuses both on how well the students understood the outcomes and identifies those students who need remediation.

The main tool used for determining the validity of criterion-referenced assessment is the outcome difficulty index which is calculated by dividing the number of students who achieved the outcome by the total number of students.

Conclusion

After performing this analysis, a refining process took place to approach different outcomes of the course. By this continuous process of outcome analysis, much was learnt about the course, instruction, and the actual examination itself. Post-examination outcome analysis has provided specific feedback for improving instruction as well as the results. It has shown that there was a 15 to 20 per cent increase in the passing rate. Specific feedback on outcomes and the time required for students to master topics were gleaned from this analysis.

Through this project, we have come to understand the value of taking an outcome-based approach to improve the practice of teaching. The time span required to perform this analysis and the increased number of students were the major hurdles we faced during the project. We found that this process is applicable for other courses to improve the efficiency of the teaching–learning process and to analyse outcomes.

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Numerical solution of differential equations using Excel

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Abstract

Numerical methods play an important role in engineering and technology. They provide approximate solutions to real-life problems which are either too difficult or even impossible to solve analytically. On the other hand, finding faster methods of implementing calculation-intensive numerical algorithms poses a challenge to computer professionals. Thus, a study of numerical methods finds a place in the curriculum of almost all engineering programmes. Effective software packages are available to augment such a study. While their importance in everyday application cannot be overemphasized, it also needs to be noted that the use of such software does not enlighten the student on the intricacies involved in the computation. Frequently, the student does not understand the nature of the analysis done by the software. Carrying out the calculations manually is not attractive either, since any non-trivial numerical problem will involve hundreds of computations. Spreadsheet packages like Excel, which is widely available, meet the requirement admirably. The numerical solution of differential equations provides a case for illustrating the use of Excel for this purpose. The student can see how one can implement a fairly complicated algorithm like the Runge–Kutta method within an hour and use it for solving a host of problems. The effect of changing the increment and the number of iterations is easy to demonstrate as well. It enables the student to learn and appreciate the measurement of error in approximation. While this paper illustrates these benefits, care is taken to ensure that the ideas learnt can be extended to implementing other numerical methods.

Introduction

Differential equations are commonly used for mathematical modelling in science and engineering. The fundamental laws of these disciplines explain variations in physical properties and states of systems. When they are combined with continuity laws for energy, mass, or momentum, they lead to differential equations (Chapra and Chanale, 1998). However, many of the differential equations of practical value cannot be solved using analytical methods. It thus becomes necessary to use numerical methods to solve such equations.

In numerical analysis, Runge–Kutta methods are important for the implicit and explicit iterative methods for the approximation of solutions of ordinary differential equations. These techniques were developed around 1900 by the German mathematicians C. Runge and M. W. Kutta. The most common is the classical-fourth order Runge–Kutta method, which it is often referred to as ‘RK4’ or simply as the ‘Runge–Kutta method’.¹ It achieves a high degree of accuracy. Given an ordinary differential equation $dy/dx = f(x, y)$ the problem is to estimate y_{n+1} using y_n . The standard fourth-order Runge–Kutta method computes four estimates and uses a weighted average of them to calculate y_{n+1} . For a step interval of h , the gradients and the next estimate are as follows:

$$\begin{aligned}k_1 &= hf(x_n, y_n) \\k_2 &= hf(x_n + h/2, y_n + k_1/2) \\k_3 &= hf(x_n + h/2, y_n + k_2/2) \\k_4 &= hf(x_n + h, y_n + k_3) \\y_{n+1} &= y_n + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4).\end{aligned}$$

The Runge–Kutta methods are used for the solution of first-order linear and non-linear equations. The benefit of the Runge–Kutta method for a time approximation is that it is more accurate than the explicit Euler method.

One way to guarantee accuracy in the solution is to solve the problem many times using different step sizes h and compare the answers with the exact solution. At each step, two different approximations for the solution are made and compared. If the two answers are in close agreement, the approximation is accepted. If the two answers do not agree to a specified accuracy, the step size is reduced. If the answers agree to more significant digits than required, the step size is increased.

Effective software packages are available to implement the algorithm. MATLAB has built-in functions to solve differential equations and also provides facilities to write one’s own code. While one has to learn a new language to write the code, using the built-in function will not enlighten the student on the intricacies involved in the computation. Frequently the student does not understand the nature of the analysis done by the software. Carrying out the calculations manually is not attractive either, considering the computations involved. Spreadsheet packages like Excel, which is readily available, meet the requirement admirably.

A spreadsheet is basically a computerised version of a large accounting worksheet. The felicity with which one can make inter-related calculation makes it a powerful tool. Previously, we described our experience in using Excel in teaching mathematics and noted how it turns students from passive spectators into active participants in the learning process (Al Rawahi, Khan and Huq, 2006). In this article, we describe the implementation of the Runge–Kutta method in Excel and the learning outcomes that can be achieved. We also discuss the possibility of developing a schema for learning and teaching.

¹<http://en.wikipedia.org/wiki/Runge-Kutta>

Implementation

For the purpose of illustration, consider the following differential equation

$$\frac{dy}{dx} = \frac{x^5 + 3y}{x}.$$

A typical exercise would be to approximate the solution to this equation over the interval $[1, 2]$ with step sizes of 0.2, 0.1, 0.05, 0.02 and 0.01 using the fourth-order Runge–Kutta method. Different approximations will then be compared with the actual solution in an attempt to discuss the importance of estimating the gradients accurately and using an appropriate step size. The student knows that the error decreases as the step size h decreases and that h is increased, where possible, to speed up the calculation, and decreased where needed to maintain accuracy. The question is: how does one strike a balance? Figure 1 shows a screenshot of the calculations done with $h = 0.2$. Figure 2 presents the exact solution along with its graph – another capability of Excel that is easy to use.

x _n	y _n	K1	K2	K3	K4	y(n+1)
1.0	1.0	1.4	1.769547	1.865242	2.347341	1.83482
1.2	1.83482	2.3301299929	2.879427	3.095596	3.696027	2.965862
1.4	2.965862	3.683377753	4.469896	4.6272	5.996955	4.579028
1.6	4.579028	5.578530849	6.67163	6.86453	8.181308	6.805360
1.8	6.805360	8.16190274	9.638098	9.871232	11.61723	9.799578
2.0	9.799578	11.50672685	13.54209	13.82014	16.08673	13.73448
2.2	13.73448	16.06337012	18.57559	18.90327	21.7914	18.80208
2.4	18.80208	21.76610232	24.94979	25.33183	28.95207	25.21366
2.6	25.21366	28.92472968	32.8951	33.33625	37.80856	33.19933
2.8	33.19933	37.77923973	42.86111	43.16613	48.62027	43.0089
3.0	43.0089	48.60804415	54.61661	55.09026	61.66549	54.91136
3.2	54.91136	61.63193873	68.74961	69.39667	77.34152	69.15438
3.4	69.15438	77.20612335	85.6673	86.39255	95.68807	86.16532
3.6	86.16532	95.6281979	105.5961	106.4043	117.2742	106.1506
3.8	106.1506	117.2341623	128.0019	128.7775	142.4215	129.4395
4.0	129.4395	142.3792166	155.8885	156.877	171.4823	156.5654
4.2	156.5654	171.4377007	187.001	188.0000	204.0502	187.7439
4.4	187.7439	204.8033945	222.6222	223.8101	242.9378	223.4343
4.6	223.4343	242.8889181	263.1744	264.4892	286.1778	264.059
4.8	264.059	286.1263315	309.0954	310.5059	336.0204	310.0686

Figure 1: Computations in the implementation of RK4 for a step size of $h = 0.2$.

Observations

Once the calculations have been done for one step size, it can be duplicated for different step sizes without much effort. In this exercise, five approximations are produced. In order to make sense out of the mass of numbers, the student extracts the information related to gradients involved in determining y for $x = 1$. Table 1 presents the result. It

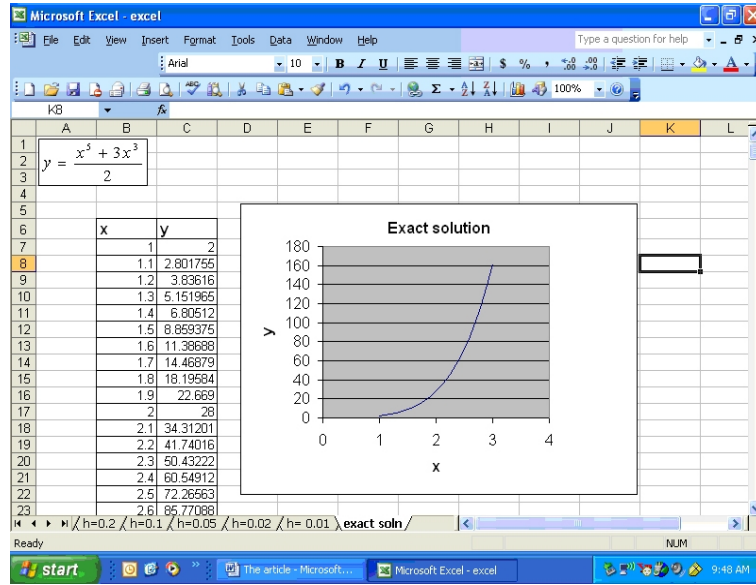


Figure 2: The exact solution with its graph.

shows the estimates of the slopes at the beginning, middle, and centre of the interval as well as the estimates of y , the true value being 6.80512.

h	k_1	k_2	k_3	k_4	k	$\hat{y}$
0.2	2.33213	2.87932	3.0056	3.69993	2.96698	6.801801
0.1	1.47448	1.64082	1.65931	1.84368	1.65307	6.804854
0.05	0.82525	0.87093	0.87342	0.92129	0.87254	6.805101
0.02	0.35273	0.36046	0.36062	0.36848	0.36056	6.805119
0.01	0.18027	0.18224	0.18226	0.18424	0.18225	6.805120

Table 1: Estimates for different step sizes.

The student is led to make several observations including:

- While the differences between k_1 and k_2 as well as between k_3 and k_4 are quite pronounced, the estimates at the centre do not differ significantly.
- Although the difference between k_2 and k_3 keeps decreasing to the point of being negligible, when $h = 0.01$ it must be noted that the magnitude of the gradient itself keeps decreasing.
- For small step sizes, even the difference between the gradients at the two ends becomes very small. As a percentage of the weighted average, the decrease is from 46 per cent when $h = 0.2$ to 2 per cent when $h = 0.01$.

- (iv) Since values of y increase by $h \times \text{step-size}$ it also brings out how y changes smoothly. The fact that y increases from 2 to 1750 corresponding to the relative small change from 1 to 5 in x is worth noting in light of the gradual increase.
- (v) A comparison with the actual value reveals that an accuracy correct to two decimal places was achieved even for $h = 0.2$. Step size of 0.05 produces accuracy correct to four decimal places.

The last point can be further elaborated with a detailed working of errors of approximation. The student is encouraged to extract from the worksheets the true values of y as well as the estimates for different step sizes corresponding to different values of x . In addition to illustrating the nature of approximations, such exercises will also train the student to interpret the content of tables and extract relevant information from a large volume of data.

Pedagogical patterns

While Excel has a large number of built-in functions, it also includes Visual Basic as a macro language that can be used to create new functions. This saves one from entering the formula in its entirety for each column again. Thus what is done for the solution of one equation can be finalised as a template and subsequently used for solving other equations. Interestingly, it ties up with a schema for teaching and learning, known as pedagogical patterns. Inspired by the idea of capturing design guidelines in the form of design patterns in architecture, pattern-based design has spread to other disciplines such as object-based design, hypermedia engineering, human-computer interaction, and e-learning (Retalis, Georgiakakis and Dimitriadis, 2006). In education, it has generated the concept of pedagogical patterns. These patterns essentially describe abstract templates from which specific solutions can be generated so that later designs do not have to start from scratch when the same problem recur. In a summary of such reusable pedagogical design patterns introduced by Susan Lily in 1996, Haberman (2006) lists the following elements: (i) the patterns must be repeatable and easy to adapt, (ii) they must be described in a way that allows them to be easily applied for different lessons by different teachers; and (iii) they do not have to be novel or original; rather, they should communicate proven solutions to common problems. Viewed in light of these ideas, the exercises presented here assume importance in teaching and learning.

Conclusion

In this paper, we have outlined the development of a template for generating solutions to ordinary differential equations and discussed the learning outcomes that can be achieved. With its emphasis on applying the learnt material and analysing the results, it motivates students to learn better. An important aspect of the exercise is its re-usability. Future work will focus on perfecting the model presented here in line with the development of the new paradigm of pedagogical patterns.

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An investigative and activity-based approach to mathematics teaching

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Abstract

Mathematics learning is not mere acquisition of knowledge and doing a set of exercises. The beauty and power of mathematics learning is characterised by pattern, relations and structures. Pattern finding is within the reach of all of us and that forms, by and large, the key for discoveries in the wonderland of numbers. Everyone is eager to find out relations not only among concrete things but also between abstract ideas according to their own levels of maturity and capability. Investigative as well as activity-based approaches of teaching may kindle mathematical thought and insight and pave the way for effective learning. This paper describes how an investigative approach to the binomial theorem and the conic sections of the parabola, ellipse and hyperbola through paper folding activities, help students to understand and appreciate the richness and beauty of mathematics while effective, active learning and teaching take place.

Introduction

The success of mathematics learning depends greatly on the amount of interaction occurring between the teacher and the student. Mathematics is a subject that can be learnt not only by listening, but also by thinking, discussing and arguing (Kapur, 1999). Such learning is further augmented through more interactive ways of learning such as an investigative approach and activity-based methods. These call for a transition from traditional practices to more interactive-based approaches of teaching mathematics. Many researchers in this field emphasise the importance of such a reform in mathematics education. From another angle, the goal of mathematics learning lies not only in solving a given problem but also in understanding the means of doing so. Students need to understand and think during the whole process, so that they develop strategies to solve other problems in similar contexts. Students acquire varied ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that serve them well outside the mathematics classroom. Reasoning and analysis help a person to note patterns, structure or regularities in not only the real world but also in mathematical situations (National Council of Teachers of Mathematics (NCTM), 2000).

Looking from the teacher's side, effective mathematics teaching requires us first to understand fully what students know and need to learn, before challenging and supporting them. With active building of new knowledge from previous knowledge and experience, students' abilities and confidence in doing mathematics are all shaped by the teaching they encounter in school (NCTM, 2000). Some such effective teaching methods are described here.

Investigative approach

Introducing 'investigations' at an appropriate level as a means of varying the styles of mathematics lessons (Costello, 1991) makes teaching and learning active. Especially when the classes are based largely on an individualised scheme, an investigation can be an appropriate way of delivering a whole class lesson, in which students can come together to discuss a mathematical situation. While providing opportunities for investigation, it is the method of exploration which is important, not the answer (Pirie, 1987). An investigation may be presented in any one of the following ways: (i) a question to be answered with a direction on how to start; (ii) a bald statement which needs to be translated into a problem; (iii) an explicit question with an answer; or (iv) a vague question which leaves the problem open-ended.

Binomial theorem

The nature of mathematical investigation in the binomial theorem is illustrated in the following example.

$$\begin{aligned}(a + b)^1 &= a^1 + b^1 \\(a + b)^2 &= a^2 + 2ab + b^2 \\(a + b)^3 &= a^3 + 3a^2b + 3ab^2 + b^3.\end{aligned}$$

While considering the above pattern, the following questions can be raised as an investigation. What observations do they make of the data above? How many terms will $(a + b)^4$ have? What will happen to the exponents of a and b ? What do you think will be the next expansion of $(a + b)^4$? These questions will motivate the students as they will not find it too difficult to get the answer and will be ready to move to the next level. Can you find a relation or rule to get each coefficient?

Students may come out with Pascal's triangle to get the next expansion. After encouragement, we can guide them to the next level by asking them to obtain a relation without using the previous expansion. This will help them to think critically. If they find it difficult to proceed, especially at this stage, they can be provided with clues to determine the next coefficient with the help of the previous coefficient, exponent of ' a ' and rank of the term.

$$(a + b)^4 = \underset{1}{a^4} + \underset{2}{4a^3b} + \underset{3}{6a^2b^2} + \underset{4}{4ab^3} + \underset{5}{b^4}$$

Multiplying the coefficient of a term by the index of ' a ' and dividing the product by the rank of the term gives the coefficient of the next consecutive term. This can be

generalised for $(a + b)^n$ as follows:

$$\text{2nd coefficient} = \frac{\text{1st coefficient} \times n}{\text{rank of the previous term}} = \frac{1 \times n}{1} = \binom{n}{1},$$

$$\text{3rd coefficient} = \frac{\text{2nd coefficient} \times (n - 1)}{\text{rank of the previous term}} = \frac{\left(\frac{1 \times n}{1}\right)(n - 1)}{2} = \frac{n(n - 1)}{2} = \binom{n}{2},$$

$$\text{4th coefficient} = \frac{\text{3rd coefficient} \times (n - 2)}{\text{rank of the previous term}} = \frac{n(n - 1)(n - 2)}{2 \times 3} = \binom{n}{3},$$

and so on.

Without the help of Pascal's triangle, students are led to the following expansion through their investigative work

$$(a + b)^n = \binom{n}{0}a^n b^0 + \binom{n}{1}a^{n-1}b^1 + \binom{n}{2}a^{n-2}b^2 + \dots + \binom{n}{n}a^0b^n.$$

Interestingly enough, Newton did not arrive at the result either in this way or from Pascal's triangle to the binomial theorem, but indirectly from a quadrature problem to the binomial theorem. Newton himself explained in detail in his letter to Oldenburg just how he had been led to the binomial series. He wrote that toward the beginning of his study of mathematics he had happened on the work of Wallis on finding the area (from $x = 0$ to $x = x$) under curves whose ordinates are of the form $(1 - x^2)^n$ on examining the areas for exponent's n equal to 0, 1, 2, ... and so on (Boyer and Merzbach, 1989).

Generating Pythagorean triplets

Study of the Pythagorean property of the right angled triangle finds an important place in mathematics curricula worldwide. Encouraging the student to discover hidden connections in Pythagorean triplets and generating them excites students, thereby providing an opportunity to promote creativity in mathematics learning. The excitement is heightened when new connections are forged among familiar themes (Srinivasan, 1992). On adding the reciprocals of any two consecutive even numbers, the numerator and denominator of the resultant number will be the first and second members of the triplet as the following two examples show.

$$\frac{1}{2} + \frac{1}{4} = \frac{3}{4} \quad (3, 4, 5)$$

$$\frac{1}{6} + \frac{1}{8} = \frac{7}{24} \quad (7, 24, 25)$$

The students may be asked to examine this pattern by taking general terms. Furthermore, they may be encouraged to investigate the consecutive odd numbers and the sum of reciprocals of them. Such an example provides students with an opportunity to enjoy the beauty of mathematics and also to understand this proposition and its limitations.

Activity-based approach

In traditional mathematics teaching the scope for activities are highly limited thus making the whole process monotonous and boring. Introducing activities to understand theorems and concepts not only breaks this monotony but also provides opportunities for the students to think, analyse, reason, and absorb these concepts. This promotes independent thinking and scope for sustained effort and time so that students will have the confidence to access and use needed mathematics and other technical information independently and also to draw conclusions from general principles. An activity like paper folding not only simplifies the learning of mathematics but also builds an experiential base necessary for further learning. Paper folding offers many opportunities for illustrating many important concepts and ideas involving transformations and geometry which are standard in mathematics curricula (Olson, 2006). Some of the activity-based approaches using paper folding techniques are described below.

The parabola

The activity which follows will help the student to understand the concept of a parabola and some of its basic properties. On a sheet of paper, mark a point 'F' on the paper preferably 3 cm above the bottom edge of the paper. Mark any point on the bottom edge of the paper and fold the paper until that new point lies directly above the point F. Make a crease in the paper, unfold the paper, choose a few more points across the bottom edge and repeat the creasing process. The creases create a curve winding partially around 'F', which is a parabola (see Figure 1).

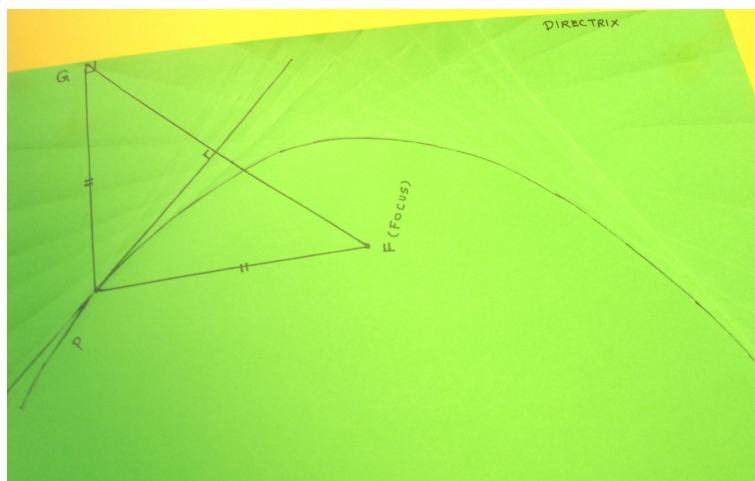


Figure 1: A parabola formed from paper folding.

On examination, it may be observed that the fold made on the sheet in such a way that a point on the edge lies directly over another, the crease is made along the perpendicular bisector of the segment joining the two points. 'F' acts as the focus and the bottom edge as part of the directrix. Also, a parabola consists of all the points that are equidistant to a focus and a directrix (distance from a point to a line is the distance

to the nearest point on the line). On considering the point G at the bottom edge, it may be noted that of all the points along the crease, the point 'P' that is directly above 'G', is the only point which is equidistant from 'F' as well as the bottom edge. Hence 'P' lies on the parabola and the crease acts as tangent to the parabola at 'P'. Moreover, all other points on the parabola are above the crease (Srinivasan, 1996).

The ellipse

Let us see how we can form an ellipse through paper folding and examine how it works. Draw a circle with 20 cm radius on a piece of paper. Mark a point 'F' inside the circle. Pick a point 'G' on the circle and make a fold so that the 'G' on the circumference gets mapped onto 'F'. Repeat the process of creasing, making different points on the circle. The creases create an ellipse inside the circle with C and F as foci (see Figure 2).

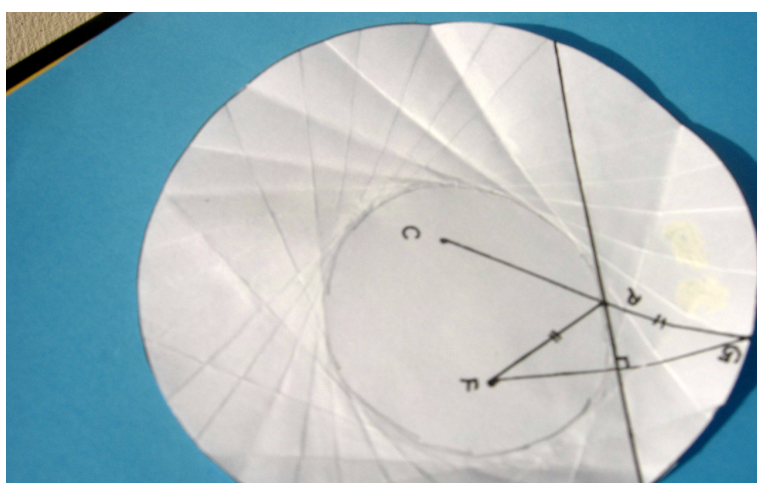


Figure 2: An ellipse formed from paper folding.

An ellipse is the set of all points whose sum of distances to two foci is a constant. Point 'P' on the crease is equidistant to C and G. It may be noted that $CP + PG = r$ where r is the radius of the circle drawn. This implies that $CP + PF = r$. Through this activity and investigation students will learn to describe an ellipse as the set of points that are equidistant to a circle and a point inside the circle (Ronning, 2001; Olson, 2006).

The hyperbola

By stimulating the students to analyse the changes in the above activity, if the point F lies outside the circle, and after investigating the activity, they understand and arrive at the result that the hyperbola is the set of all points whose difference in distance to the two foci is a constant (see Figure 3). It can also be described as the set of all points that are equidistant to a circle and a point outside the circle.

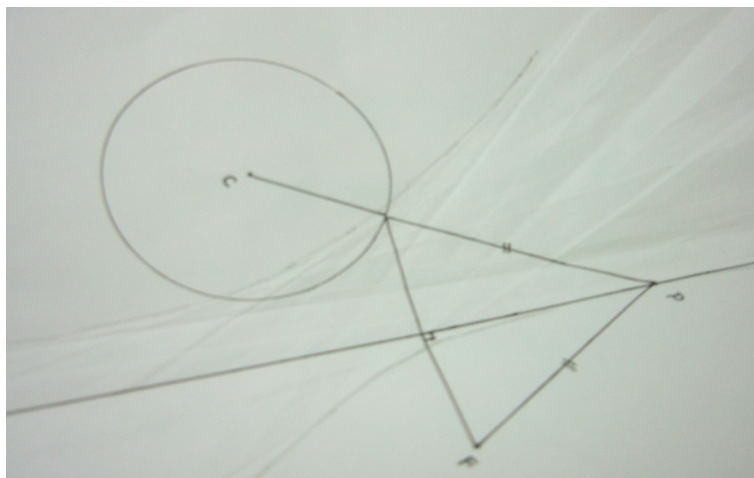


Figure 3: A hyperbola formed from paper folding.

Conclusion

Investigative and activity-based teaching of mathematics are proving to be effective for both teachers and students alike. Importantly, such approaches initiate the required interaction to happen in the classroom for mathematics learning to be more effective. The above examples have been tried out within classroom situations and found to be effective with students at all levels. Such an approach makes the mathematics learning process more dynamic.

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Study on interactive software in a mathematics classroom

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Abstract

The use of a computer-based teaching program was investigated with college-level and mature second language (Arabic mother tongue) numeracy mathematics learners within a PC tablet-wireless environment. This paper reports the findings from a study evaluating the effectiveness of this medium in enhancing learning for sixty students distributed across three classroom sections. Pre- and post-questionnaires, student satisfaction surveys, and the analysis of problems related to technology adoption are discussed. There is no analysis of learning achieved by the participants because of the connectivity problems as well as the language issues with the L2 students. Rather the research will surprisingly reveal increased motivational levels despite the disappointment incurred with software and opportunities to provide an altered approach to using technology in teaching.

Introduction

This study was conducted during the months of March through to June 2006 using mathematics students from a Al Ain Women's College in the United Arab Emirates. The students involved in the study are all in the Diploma Foundations programme, a very basic elementary level mathematics class, and range in age from 18 to 42. All are female. Three classes were selected based strictly on a volunteer process by their teachers. This introduces an unavoidable bias.

The educational background for these students has all been in Arabic, their mother tongue, and once they reach college their education is exclusively in English. They have had English for approximately ten years but not as a means of communication, rather as a class where they learnt the vocabulary using rote memorisation methods. When students are asked if they use English outside the classroom their typical response is one of 'Yes. To order fast-food' (Syed 2003).

The mathematics classes participating in the study were one each of lower proficiency English, medium proficiency English, and higher proficiency English. Specifically the average IELTS¹ for these students was 1.5. This places them in one of the following ranges: extremely limited users, intermittent users, or non-users.

¹International English Language Testing System

Background on the researcher

Many have argued that motivation should not be a priority at the college level but this researcher disagrees. High quality learning will not take place no matter how motivated the participant is, unless there is some reason for the process. Motivation must be intrinsic rather than the behaviourist belief of external motivation. If the motivation is external then the learning is not meaningful to the student and is not as likely to be retained.

Looking at the quote ‘The context is meaningful to the learner in the sense that it offers a very personal degree of fascination and intrigue’ (Rieber, 1991, p. 320), I design my approach to teaching in a way that strives to generate internal motivation using the idea of intrigue. It is more like the constructivist view in that making meaning gives the whole process more significance to the student and, moreover, is helpful in retention. I welcome the opportunity to carry scales, rulers and measuring tape into the classroom and have the students weigh me and measure my height and then calculate my body mass index and then calculate each others. That, compared to the traditional method where I show them the formula and they plug in values, is by far a more meaningful experience for the students and one they will retain longer.

Authentic activities bring much more relevance to the lesson and allow the learner to understand more thoroughly the concept being taught. One way to teach percentages is to work through the problems from their textbook and check the answers in the back of the book. Instead, I prefer to generate conversation about a pack of bubble gum and its ingredients. We come to realise the main ingredient is sugar and then I guide the discussion to the amount of sugar actually in the gum. We end the activity by weighing the gum, then chewing it until the taste (sugar) is gone, and then weigh it again and discover for ourselves how much of the gum is actually sugar. The students could then compare the answers that other groups arrived at and see if the sugar content varies depending on the brand of gum. The activity can then be extended to include the use of laptops to generate an Excel file and create graphs which clearly show the sugar content of various types of bubble gum. Which method is likely to involve more student participation, interest and enthusiasm, engaged participants and deepens their understanding of the content? Which method provides the ability to relate something inside the classroom to something outside of it?

I have not referred to teacher motivation. Not only are the students bored with lectures but frankly, as a teacher, I am as well. Just how much excitement can you generate by long division of decimals? With additional time and resources, I can make every concept authentic. However, that is not practical and that is where I believe computers can make the difference for us as educators.

It is up to the teacher to make the class challenging, interesting, and one the student wants to attend. Even with the most attentive learners who see relevance in a learning task, motivation can wane as an activity wears on. One of my favourite quotes is by Chomsky (1999) where he says ‘... as educators it is our job to arouse the natural curiosity of students and stimulate their interest in exploring on their own. What they learn passively will quickly be forgotten but what they discover for themselves when their natural curiosity and creative impulses are aroused not only will be remembered but will be the basis for further exploration and inquiry and perhaps significant intellectual contributions’ (p. 134). Therefore the purpose of this research is to examine

critically the method or delivery of materials in our mathematics classrooms. I have no doubt there are the traditionalists who remain unconvinced and want to carry on with the conventional methods. I only ask that I never be placed in one of their classrooms.

Background on the trialled software

The software trialled was *PLATO Interactive Mathematics* software,² Pre-algebra 1994–2004. The goal of implementing a multi-media learning system was to provide an alternative learning environment for students. The software package offers similar content the students would receive in a traditional lecture-type class. The advantage of this software package is that it is diagnostic and individualised. The students are assessed at the beginning of each unit and their lesson is prescribed individually based on their pre-test results. However, they can repeat or include extra practice and content if they choose. It is student-centred and designed to foster individual responsibility and motivation. It offers various learning strategies and provides adequate opportunities for practice. Learning is promoted through activity that entails continuous feedback and positive reinforcement. This is important according to Williams and Burden (1997) because if individuals are eventually to take control of their learning it is imperative they foster the ability to self-evaluate without needing feedback from the teacher. They go on to say that as the students learn to monitor their own progress in learning, which this software will allow them to do, they come to recognise personal changes as continuous, lifelong and within their own power. I think this software, or something similar, could potentially be the first step to moving students in that direction.

The teacher can monitor student progress as the system records the number of minutes the student is actively working during log-on time. Both the teacher and student obtain immediate feedback on short test items. Students are provided with correct answers, as well as various methods of attaining them if their responses were incorrect. One feature that is utilised as a result of wireless Internet connection is the expression editor. This allows students to solve mathematics problems by a multitude of means as long as the answers are correct. It is essential that students recognise there is more than one possible method to employ in order to obtain solutions in mathematics. Normally, technology-based methods do not provide for this option.

Selected key words utilised in lessons are underlined so that students can click on them to obtain a definition and example. There are certain frames with a telephone icon that provides students with access to a variety of options for help. Assistance can be in the form of e-mail, examples, practice questions, as well as a glossary complete with journal where students can take notes, etc., all of which reflect a multitude of learning styles.

Teachers can include links to their own web pages or other useful sites that offer instructional materials when desired. The courses can be customised to provide details about assignments, schedules and content as necessary. Alternative explanations for difficult concepts can be added as well.

²Available from: www.plato.com

The research begins

The first session was Sunday 26 March 2006. Students who were able to log on only to find that instead of ratios and proportions, they were forced to study graphs and tables. Although the class was set up to study ratios and proportions first none were allowed access to this particular unit. Many students were unable to log on because passwords had been entered incorrectly. Their passwords were to be the last four digits of their college identification number. Some were finally able to log on by using the last five digits.

It became immediately obvious that headphones were required. While the software package allows students to progress at their individual pace, the instruction includes speaking, and fifteen different sets of instructions could be heard at the same time from within the classroom. As the students moved their laptops around the room to find a quieter spot, some were disconnected due to proximity with the wireless connections.

The students complained that the rate of speech was too fast. They were reminded they could go back and listen again, but this was of little consequence as they were unable to decipher the English no matter how many times they listened to it. Additionally, the constant disconnection problems led to observable frustration at times for not only the student but the teacher as well.

Another constant problem the students experienced was that laptops repeatedly froze while the program was in use, even if the application was not running but the program was open. The cursor would not work and the only remedy was to close the application. By accessing the task list and clicking on End Program, the remaining programs were then accessible.

During the second lesson, it was much easier for the students to log on. Before the application started running, the classroom was unusually quiet. This is particularly odd for a classroom with fifteen students. Signing on was impossible for some students. It took a long time for them to connect and some were unable to log on for the duration of the class period. There were obvious problems with the connection. However, it was not immediately obvious if this was a wireless issue or not. Some of the special features discussed earlier, like expression editor are of no advantage if the Internet connection is disrupted. Furthermore, the students complained that when they clicked on an underlined word to have the definition explained, they were unable to understand the level of English in the definition, and found this feature of little use.

The students were encouraged to log on outside of class. However, according to the tracking record (the software allows the teacher to see how much time each individual is spending online, how active they are, and what their test scores are at any given time) none were successful. In the end, the students in three different classes used this software a total of six periods per class.

Evaluation

Given the relentless connectivity problems associated with this software, an ideal plan at this stage would have been to do some individual one-on-one user testing sessions to collect more detailed observations. This was simply not possible. Using this software took time from their normally scheduled classes and it would possibly have compromised the students' abilities to complete the class successfully had anymore class time

been taken from them.

With hindsight, perhaps I should have asked the students to begin the section with the pre-test provided by the software and recorded those scores. Then I could have compared their post-test results with other classes who used the traditional classroom method. This was something that could have been accomplished with little chance of compromising their ability to finish the class on time. However, it did not occur to me until I was analysing the results. Furthermore, because of the problems with the software, I did not feel I would have an accurate measure of their knowledge anyway.

One more suggestion that I arrived at after the study was over was that I should have asked the students themselves how the software could have been easier to use. I have some ideas myself but confirmation from them would have been beneficial.

Looking at the results of the pre-activity questionnaire (see Appendix A) in Table 1, it is obvious that the students believed they were good mathematics students at secondary school but not as many agreed that they were good mathematics students in college. This could be related to the fact that the instruction delivered in secondary school was in Arabic. They are keen to learn mathematics using a computer but worry that their English skills are insufficient to do so. They were not intimidated by the technology and seemed willing to give it a try.

Question	Strongly disagree	Disagree	Agree	Strongly agree
I was a good mathematics student in secondary school	–	3	21	21
I did not enjoy mathematics in secondary school	15	15	15	–
I am a good mathematics in college	–	24	18	6
I would enjoy learning mathematics using a computer program	3	6	24	9
I think my technology skills are good enough to learn mathematics using computer programs	6	9	18	9
My English is not good enough to allow me to learn mathematics using computer programs	–	15	27	3

Table 1: Pre-activity questionnaire.

It became obvious that part of the reasons for their lack of skills in general was due to their lack of studying outside the classroom. They have been taught that for every hour they are in the class, they should spend as a minimum one hour outside the classroom studying. From Table 2, it is apparent they are not doing this. Two even admitted to not studying at all outside of class.

Looking at the individual questions, it becomes apparent that the students were eager to learn using their laptops. They were not intimidated by the fact that their

Hours spent per day	0	1-2	2-3	3-4	4-5	8	10-15	Other
How much time do you spend using your computer each week?	3	9	3	3	6	–	6	every-day
How much time do you spend each week studying mathematics outside of class?	6	21	12	–	–	1	–	–
What is your age?	18 3	19 18	22 14	23 2	25 6	42 1		
I have studied using computer programs before	No – 30				Yes – 15			
If yes, what subject	Computer		Computer		English & Computer		Computer	

Table 2: Study habit data.

teacher was not teaching, and overall they enjoyed using them to learn mathematics. Question 1 of the post-activity questionnaire (see Appendix B) asks if they enjoyed using the computer to study ratios and proportions and seventy-four per cent either agreed or strongly agreed. Over half, fifty-three per cent admitted they had difficulty understanding the language, but seventy-six per cent either agreed or strongly agreed that they liked the help features. Interestingly, eighty-nine per cent said they would like to learn other subjects using this type of software and ninety-six per cent thought it would be a good idea to use the software sometimes and have the teacher teach other times. Fifty-nine per cent admit that they found the software more fun than having the teacher teach and seventy per cent did admit that they spent more time using this than studying mathematics the traditional way.

The following conclusion can be made. The students are very motivated to work on their laptops. Motivation increases when classroom lessons involve this mode of delivery. The problems occur when technology fails, including: not being able to log on, being unable to access the appropriate lesson, having an hour glass appear on their screen for an extended period of time, of having to shut down and reboot.

There are no behaviour issues with the students when they are engaged in this computer-based type of activity. Although these students are very well behaved, talking can be a problem on occasion in the traditional classroom setting. Active engagement is also hard to judge in the regular setting but not in this instance. The students were clearly engaged as long as they were not experiencing technical difficulties or problems understanding the language.

The students found fault with the level of the language presented. Replaying the same frame repeatedly was considered pointless when the rate of speech was too fast. The language is designed for native English speakers. On several occasions, the students had more questions after a program explanation was provided than prior to it. The curriculum is a standard American curriculum and does not match the level of need for

these particular students. There were very few topics that could even be trialled.

Proposal

It seems as though the students enjoyed using laptops. The problems appear to lie with this specific software package. Perhaps a software package that combines both audio and written text at the same time would be beneficial. The students could have the option of using audio only, video only, or both. Furthermore, it would seem a software package specifically geared for students at this level needs to be designed. It could utilise some of the beneficial ideas from this software package. This would involve using programs like Flash, where the students can interact with the lesson. The curriculum could be designed to fit with the needs of these students, rather than matching the American curriculum. Ideally it would need to be a blended course where a number of topics were taught using the traditional lecture method and others taught using laptops while others used both.

Using a soft-copy of our textbook and combining it with videos made by the various teachers on the team could be designed. The videos would need to be placed on the shared drive, due to the amount of space they would require. Students could then be presented with links to take them to the videos as often as they wanted to. This would require very little extra work on the teachers' part as they would simply record themselves during one class period or even outside of class, doing what they do in class. The teachers could each explain the content in various ways in an attempt to get at the different learning styles in the same vein as the software. The language also needs to be at a level that ESL students can understand. The teachers are in a position to provide this since this is how they convey the content to the students at present.

Ideally, a culturally appropriate curriculum would be beneficial as so many of the questions referred to US dollars or words more common in America. If it were more culturally appropriate, the authenticity of the content would take on more meaning for the students. With this, the level of comprehension should also improve (Driscoll, 2005; Oxford 2000; O'Malley and Chamot 1990). All of this could be incorporated into the teachers' recorded lesson.

In addition, websites and interactive activities found on the web³ could be incorporated when applicable. The technology problems could easily be overcome if the students used these tools, their text in soft copy, and WebCT which is frequently used in other classes to provide content interactively. In designing this approach it would also benefit the students if they had the option to look up low-frequency words electronically and access Arabic translation. These suggestions are based on the post-activity questionnaire, with particular attention to the positive points brought out by the students and the problems they encountered with connectivity.

All learners are different and will bring to the learning process a unique set of personal attributes and preferred ways of learning (Williams and Burden, 1997). As a result, they will not all go about learning the same concept in the same way. The approach I am describing here provides teachers with a way to present mathematical content in different ways and include a variety of language learning activities as well

³See, for example, www.explorellearning.com

as learning preferences. Some will be auditory, some visual. Some will involve movement, some interactivity, and some a more traditional approach. In my opinion, all will involve increased motivation. According to Williams and Burden (1997), this will help to encourage learners to find their own style and identify their own strengths and develop their own self-knowledge. They go on to say that learners learn better if they feel somewhat in control of their learning. The context and consequences will have a direct effect on a students' continuing motivation to learn (Driscoll, 2005). Motivation seems to be enhanced when the learners' expectancies are satisfied and they can attribute their success to their own efforts and learning strategies. Moreover, language learners must seek out or create opportunities to practice their language skills if they want to reach moderate to high proficiency (see, for example, Oxford 1990). With these technological opportunities at their finger tips, the students would be able to access this not only during class time but even from home.

Regarding the mostly positive points brought out in the post-activity questionnaire, as von Glaserfeld says (see, for example, Williams and Burden, 1997) 'Problem solving is undoubtedly a powerful educational tool. However, I would suggest that its power greatly increases if the students come to see it as fun' (p. 50). It would appear from the students' responses they thought learning mathematics using their computer would be an enjoyable experience.

Von Glaserfeld (1995) goes on to say 'Constructivism cannot tell teachers new things to do, but it may suggest why certain attitudes and procedures are counter-productive, and it may point out opportunities for teachers to use their own spontaneous imagination' (1995, p. 177). So using my imagination, I envision my students learning this way, looking forward to coming to mathematics classes, working outside of class and enjoying the whole process and having fun. I expect higher quality learning in general as the lessons would hold more personal relevance to the students. Designing a programme that meets the language needs of native Arabic speaking students, as well as the standards they are to meet in a culturally appropriate manner, through the use of both laptops and lecture methods via WebCT and other interactive sites where applicable seems to be vital at this time.

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Appendix

A. MATH0155 pre-activity questionnaire

Key: SDA = Strongly Disagree, DA = Disagree, A = Agree, SA = Strongly Agree.

1. I was a good mathematics student in secondary school.

☐ SDA ☐ DA ☐ A ☐ SA

2. I did enjoy mathematics at secondary school.

☐ SDA ☐ DA ☐ A ☐ SA

3. I am a good mathematics student at university.

☐ SDA ☐ DA ☐ A ☐ SA

4. I would enjoy learning mathematics using a computer program (the teacher would be in the room).

☐ SDA ☐ DA ☐ A ☐ SA

5. I have studied using computer programs before.

☐ Yes ☐ No

If yes, what subject or class was it?

6. I think my technology skills are good enough to learn mathematics using computer programs.

☐ SDA ☐ DA ☐ A ☐ SA

7. My English is not good enough to allow me to learn mathematics using computer programs.

☐ SDA ☐ DA ☐ A ☐ SA

8. How much time do you spend each week studying mathematics outside of class?

9. How much time do you spend using your computer each week?

10. How old are you?

B. MATH0155 post-activity questionnaire

1. I enjoyed using the computer to study ratios and proportions.

☐ SDA ☐ DA ☐ A ☐ SA

2. I enjoy using my laptop to learn mathematics.

☐ SDA ☐ DA ☐ A ☐ SA

3. It is hard to learn mathematics from the computer.

☐ SDA ☐ DA ☐ A ☐ SA

4. I had difficulty understanding the language.

☐ SDA ☐ DA ☐ A ☐ SA

5. I liked the videos in the software package.

☐ SDA ☐ DA ☐ A ☐ SA

6. I like the help features in the computer program.

☐ SDA ☐ DA ☐ A ☐ SA

7. I would like to learn other subjects using this type of software.

☐ SDA ☐ DA ☐ A ☐ SA

8. I can learn mathematics just as well from the computer as I can from my teacher.

☐ SDA ☐ DA ☐ A ☐ SA

9. I think it would be a good idea to use the computer some times and have my teacher teach me sometimes.

☐ SDA ☐ DA ☐ A ☐ SA

10. Did you spend more time studying using this software than you do studying mathematics the traditional way?

☐ SDA ☐ DA ☐ A ☐ SA

11. I had more fun learning mathematics this way than having my teacher teach.

☐ SDA ☐ DA ☐ A ☐ SA

12. What aspects of using this software did you enjoy? Tick any that apply.

- ☐ I could work at my own pace.
- ☐ I like working with my laptop.
- ☐ It was easy to use.

- ☐ I prefer this rather than listening to my teacher talk.
- ☐ I liked the examples.
- ☐ I liked being able to go back as many times as I needed to get help with something I didn't understand.
- ☐ I like the idea of being able to use this from home if I want to.

13. What aspects of using this software did you not enjoy? Tick any that apply.

- ☐ I didn't like working at my own pace.
- ☐ I don't like doing my work on my laptop.
- ☐ It wasn't very easy to use.
- ☐ I prefer to have my teacher teach me rather than learning on my own.
- ☐ I didn't like the examples.
- ☐ Being able to go back as many times as I needed to wasn't helpful to me.
- ☐ I would never use this from home.

14. If I could access this software package at anytime, and it contained more sections that were included in this mathematics class, I'd use it to help me study outside of class.

☐ SDA ☐ DA ☐ A ☐ SA

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From disorientation to application: Integrated mathematics and computing tasks

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Abstract

Education ministries in the Gulf region in general, and the United Arab Emirates in particular, have recognised that reforms are required at all levels of education. The Ministry of Education and Youth has developed Vision 2020, an ambitious initiative to shift the focus from passive to active learning. Active learning is process-based and experiential, empowering students to internalise, reflect on, and externalise concepts. Active teaching, therefore, must be the facilitation of active learning and as such encompass the teaching of transferable skills intricately connected to real-world application. This paper introduces the Research Skills and Projects (RSandP) course, which was implemented for first-year students at Dubai Men's College to effectively facilitate students' transition to active learning. Employing a design underpinned by sociocultural theory and adult learning principles, RSandP aims to achieve a paradigm shift in students' attitudes to, and achievements in, learning. The course also ensures that mathematics and computing are dynamically related to other disciplines by providing tasks that are relevant to project work. The tasks require that students not only understand underlying mathematical and computing concepts, but are also able to apply them. Students actively engage with tasks, peers, teachers and the community, frequently through computer-mediated communication, as well as self-generating and analysing their own data. In this paper we refer to the findings of a longitudinal research study which indicates that students doing the RSandP course are able to analyse problems and apply appropriate mathematical concepts and computing skills outside the classroom.

Introduction

Adult education as a field of study has attempted to best meet the unique needs of adult learners by utilising adult learning principles to develop their educational practice. Adult learning theorists such as Daines, Daines and Graham (1995), Knowles (1990) and Mezirow (1991) have all developed sets of learning principles which can influence strategies employed by teachers and, consequently, can significantly enhance the quality of learning achieved by students. Reiterated by all adult learning theorists is the requirement that adult learners be actively involved or engaged in the learning activity.

Initiating a switch from instruction-oriented education to self-education, The United Arab Emirates Ministry of Education and Youth (MoE) (UAE Ministry of Information and Culture, 2005) is espousing a move away from passive learning toward active learning. Active learning can be considered as process-based and experiential, empowering students by introducing them to the process of internalisation of, reflection on, and externalisation of concepts. Therefore, active learning focuses less on task completion and formal assessment, and more on equipping students with the ability to interpret and apply acquired learning in real-life contexts, i.e. the focus is on the process rather than the product. Active teaching, therefore, must be the facilitation of active learning and as such encompasses the teaching of transferable skills intricately connected to real-world applications.

Seels and Glasgow (1998) indicate that instructional designers strive to translate the principles of learning and instruction into specifications for instructional materials and activities. They argue that adherence to the principle of 'active teaching, active learning' should result in learning environments which are student-centred, process-based and experiential. Opportunities are thereby made available for students to develop and enhance self-directed learning, which is a characteristic inherent in all adult learners, but one which needs to be encouraged and actively mentored by educators.

Cooperative learning (Tanisli and Saglam, 2006) is an approach which readily provides opportunities for learning in real-world contexts with authentic application of tasks, as well as naturally integrating active learning processes such as investigational work, problem solving, small group work, collaborative learning and experiential learning. This paper introduces the Research Skills and Projects (RSandP) course, which was implemented for first-year students at Dubai Men's College (DMC) to effectively facilitate students' transition to active learning. The paper will also discuss, in detail, the initiative to integrate key mathematical learning activities within the course and explain the steps followed to ensure that the learning strategies employed adhere to the principle of active teaching and active learning.

A disorientation dilemma: The educational continuum in the UAE

Since the establishment of the United Arab Emirates (UAE) Federation in 1971, the MoE has recognised the challenges it faces if it is to meet the needs of students (UAE Ministry of Information and Culture, 2003) who need to acquire and develop critical thinking and problem-solving skills so as to be able to function in tertiary education and the work force (Yildirim, Kamuran and Ayten, 2006). As a result, education ministries in the Gulf region in general, and the UAE in particular, have recognised that reforms are required at all levels of education. The MoE, for example, has developed Vision 2020 (UAE Ministry of Information and Culture, 2004); an ambitious initiative to shift the focus from passive to active learning to implement 'a holistic approach [to learning] that sees the student rather than the teacher as the centre of the educational process [which] requires a total rearrangement of teaching values and methods' (p. 214). DMC, part of the wider organisation of the Higher Colleges of Technology (HCT) in the UAE, is a tertiary, English language medium educational establishment for Emirati males. In addition to the challenge of using English as the primary study medium, students must also adapt to a student-centred teaching approach and adopt

a self-directed learning style that requires them to take ownership of their own learning, a concept seldom encountered in schools to date (United Nations Development Programme, 2003). A deficiency in English language skills coupled with poor study and analytical skills leads to high occurrences of uncertainty, insecurity and confusion (Owen and Durham, 2006). As adult learners, the students at DMC inherently possess self-direction skills that must be developed and mentored (Knowles, 1990). Thus, the focus of the collaborative learning approach utilised in RSandP ensures that students are assisted in overcoming the disorientation resulting from the conceptual change encountered when changing from a teacher-centred to a learner-centred approach.

Active teaching, active learning strategies

Employing a design underpinned by sociocultural theory and adult learning principles, the RSandP course aims to achieve a paradigm shift in students' attitudes to, and achievements in, learning. The course was developed to address specific deficiencies recognised and documented by the UAE MoE, and is designed to scaffold students through their disorientating shift from passive to active learning. From conception, the course was designed to be collaborative as well as challenging students' perceptions, and, as such, makes use of strategies such as cooperative learning tasks. Roger and Johnson (1994) indicate that interaction between students can take three main forms: (i) competitive, (ii) individualistic and focused on meeting goals, and (iii) cooperative, whereby the success of the team is reliant on the learning success of each individual.

Cooperative learning involves working in a group, undertaking tasks that encourage positive interdependence, individual accountability, interpersonal skills, communication skills, use of higher-order thinking skills and awareness of team dynamics, all to achieve a common goal that will be evaluated (Roger and Johnson, 1994). Teams can be self-elected or selected by a teacher to ensure a combination of levels of ability and expertise. In the latter, often the motivation of successfully assisting team mates is high, and the process of externalising a concept enforces the skill or concept for the student performing the explanation.

The RSandP meets course objectives of core subjects such as English, computing, mathematics and information literacy skills. Mathematics (Tanisli and Saglam, 2006) is recognised as a branch of science which enhances the development of behaviour such as logical thinking, decision analysis, drawing logical conclusions, effective communication, making justifiable generalisations, and creative thinking.

It is therefore logical to conclude that mathematics tasks need to be integrated to provide students' with greater mental challenges and opportunities to solve the holistic problems they are likely to face while studying and working.

Particular mathematical skill deficiencies consistently identified in Foundation students by DMC teachers include (Ali, 2006):

- using analytical and problem-solving skills;
- understanding mathematical terminology in English;
- understanding the language structure and grammar of word problems;
- applying problem-solving and analysing skills to produce correct answers;

- employing self-directed study skills; and
- adopting different learning strategies to address new mathematical ideas and concepts.

The RSandP course ensures that mathematics and computing are dynamically related to other disciplines by providing tasks that are relevant to project work and which recycle key vocabulary and language structures. The tasks require that learners not only understand underlying mathematics and computing concepts, but are able to explain them and apply them in real world contexts. Students actively engage with tasks, peers, teachers and the community, frequently through computer-mediated communication, and also self-generate and analyse their own data. These convergent learning experiences prepare students for the real-world, a world that is not divided into academic disciplines.

For a course to be effective, it is important that instructional decisions are made based on learning outcomes and key principles. To help ensure adherence to the crucial principals of active teaching and active learning, the RSandP development team employed the following core strategies when designing and developing the course's learning tasks:

- integrating process-based, cooperative and experiential learning activities which empower students to internalise, reflect on, and externalise concepts;
- teaching transferable skills;
- facilitating the development of students' self-direction;
- assigning investigational work, problem solving, and small group work;
- integrating activities that require students to interpret and transform information, and to draw logical and justifiable conclusions from data; and
- employing technology and media, not simply to deliver learning, but to enhance it.

Approaches to the application of mathematics

The following section of the paper describes two fully-integrated mathematics projects that have been run as part of the RSandP course in the 2004–2005, and 2005–2006 academic years. Each year has seen enhancements and additions to the mathematics tasks in response to research data and feedback from stakeholders. The description below is the most recent version of the mathematical tasks.

Project 1 – Careers: Decision analysis activities

In Semester two of their Foundation year at DMC, students are required to make a decision regarding which specialised course to enrol in, selecting from the following course options: Business, Aviation, IT, Communications Technology, and Engineering. For the most part, students are unsure as to which speciality might be suitable for their interests and skills, and what employment opportunities are available to them following the completion of a course. The task facing the RSandP team was to design learning

experiences adhering to the principles of active teaching and active learning in such a way that the learning goals and objectives could be achieved. The decision analysis tasks developed in response to this problem consisted of two subtasks.

Beyond the classroom task (BTC)

All aspects of the task were completed in small groups, independent of a teacher. The off campus BTC task required students to interview people in the workplace and gather current data on employees' occupations, skills sets, and educational standards. Students also gathered and sorted data on the respondents' nationalities and the respective proportion of nationalities in the public and private sector. As a final step, data was represented in graphs and used to answer questions on the implications of the responses on themselves, their respective careers decisions, and where their courses may lead them. As such, the task was specifically designed to encourage the use of critical thinking skills, as well as to interact with mathematical data for practical purposes.

Next, students listened to an audio podcast of an interview with two Emirati students discussing what course they are considering studying in the following year. One student made mention that he had only one consideration, the second provided a more reflective explanation outlining several factors he had considered prior to making his decision about his course of study. RSandP students were asked to reflect on the responses of the two interviewees, answer questions on what was discussed and comment on the considerations provided. Students, working in small groups, then created a list of considerations which could be used to assist students when making a decision about which course to undertake. This task was used to ensure that students reflected on and internalised the importance of considering a number of factors when making decisions, prior to undertaking the decision analysis activity.

Career decision analysis activity

Subject matter experts within each of the possible departments that students would be graduating to had presented the RSandP team with a list of skills and attitudes required of students who intended to undertake their course. Also included was specific information about the different courses offered by each department and the job opportunities which would be available following graduation from DMC. This information was used to script scenarios which required students to read information about a given situation, analyse the various course options available, and using a list of considerations, decide which course is best suited to the individual. An example of one scenario is shown in Figure 1. Whilst it was believed that the consideration list would enable students to make better decisions, it was felt that it did not sufficiently address the UAE government's policy of Emiratisation and the impact of this in the decision making process.

To ensure the process would soundly address all central factors, students were set the task of investigating the UAE government's policy of Emiratisation. Students gathered data on what industries were subject to national quotas and the specific percentage quotas set, as well as the statistics on how effective the programme was in practice. In addition, students researched which courses at DMC led students to jobs in these industries. Using their mathematics skills, calculations were performed and the data gathered was interpreted. The research articles and questions were presented as part of a WebCT quiz, which automatically marked and provided students with specific feedback on their responses.

Read Ali's 'career needs'. Then listen to information about three possible career choices for him. Use your considerations list to decide which course is best for him.



Ali enjoys maths, hands-on activities & is doing well at English. He is an organised, sociable person who enjoys problem solving & likes working with people; last summer Ali helped his older brother at DEWA who sponsored his studies. However, Ali thinks he would like to work in the private sector.

Business seeks students with good organisational skills, who pay attention to detail, like working with numbers & are able to communicate well in English. Career opportunities include banks, accounting firms, insurance & financial companies & the government.

Comm Tech seeks students who enjoy working with photography, video & graphics, computers & like working as part of a team. Career opportunities include television broadcasting, web & graphic design, public relations & advertising.

Engineering seeks students who like building, solving technological problems, enjoy working hands-on and who like to fix & improve things for other people. Employment opportunities include government agencies such as DEWA, as well as oil companies and construction firms, eg Emaar.

Figure 1: Example of a career decision analysis activity.

Students were then required to reflect on the effectiveness and shortfalls of the policy and internalise their perspective on how important the consideration of Emiratisation would be when undertaking their career decision process. This was facilitated through group discussion. As a result of this integrated task, students were able to add Emiratisation to their considerations list and expand their decision making approach, as shown in Figure 2. The activity provided students with the opportunity to actively employ their mathematics skills to effectively enhance their ability to solve problems in a real world context of personal relevance. This type of activity would have been difficult to utilise in 'stand-alone' mathematics classes, as students would not have had the career context provided by the RSandP project.

Project 2 – Innovation and change: Development of mathematical ideas through history

The history of mathematics can be naturally integrated in active learning processes (Yevdokimov, 2005). Man-Keung (1996) presented the ABCD for the use of history of mathematics in the undergraduate classroom: A for anecdotes, B for broad outline, C for content, and D for development of mathematical ideas. He explained that historical context can be used to forge links of cultural history or to emphasise a concept or idea. The RSandP course incorporates a module entitled 'Inventions, Developments and Change' which provides an excellent context to address the D in the ABCD model; the 'Development of mathematical ideas' for Foundations students.

A key idea to be fostered was to let students investigate historical material and to 'learn from the masters' (Man-Keung, 1996, p. 44). In this instance, the instructional

Foundation students at DMC	Possible courses for Year 2		
Course Considerations	Course 1	Course 2	Course 3
Personal			
Does the student have a general interest in this area of study?			
Emiratisation			
Does the course lead to private sector jobs with Emiratisation quotas?			
Academic			

Figure 2: Considerations when choosing a DMC Higher Diploma course.

objective was to let students experience, through the work of historical Islamic mathematicians, how the masters went about their jobs. The historical context in active learning of mathematics was to be used to develop students' abilities to analyse mathematical content from today's point of view and to perceive the evolutionary development of mathematical concepts. Additionally, the effective exploitation of historical context was intended to contribute to the development of the creative thinking of students.

Historical background to the applied mathematics task

The eighth-century heralded the golden age of Islamic civilisation (Singh, 1999). The ninth-century scientist, Abu Yusuf Ismail al-Kindi – known as 'the philosopher of the Arabs', invented cryptanalysis, the science of unscrambling a message without knowledge of the key. This technique showed that it is possible to reveal the contents of a scrambled message simply by analysing the frequency of the characters in the cipher text. The Arabs used this process as a method for breaking the mono-alphabetic substitution cipher; a cipher that had remained invulnerable for several centuries.

The development of this process (Singh, 1999) came about as a result of Muslim theologians' scrutiny of the Hadith, which consists of the Prophet's daily utterances. They tried to demonstrate that each statement was indeed attributable to the Prophet Mohammad (peace be upon him) by studying words and the structure of sentences to test whether particular texts were consistent with the linguistic patterns of the Prophet. The religious scholars also analysed individual letters, which led them to discover that some letters are more common than others. The letters 'a' and 'l' are the most common in Arabic. This observation resulted in the first great breakthrough in cryptanalysis.

Development task

The first task students were required to do was to follow the active process of scrutinising three articles, which had been written by two authors. Students were given the authors of the first two articles, and challenged to see if they could guess which of these writers was the author of the third article. Students were encouraged to undertake their investigative work in pairs and were provided with time to brainstorm approaches to address the problem presented. Through guided questions, teachers elicited strategies from students such as, examining patterns in the author's meta-language, sentence structure, word frequency and vocabulary use.

Students were then invited to re-attempt the task, however, this time they were provided with a tool to assist the process: TextSTAT a simple program for the analysis of text. The program (Hüning, 2006) reads both Microsoft Word and HTML files and produces word frequency lists and concordances from these files. TextSTAT had previously been used by students when learning about paraphrasing as part of the RSandP course, and consequently, students were comfortable with the technology and little time required to access and utilise it. Students were also provided with word frequency lists for the first two articles for comparison analysis, and as such, were able to employ TextSTAT to generate frequency tables. Discussion was conducted about the effectiveness of both approaches and the use of mathematics and technology in tackling the task.

Students next listened to an audio podcast which outlined the historical Arab contribution to the innovation of coding. The recording clearly stated the process undertaken by the Islamic mathematicians which led to the breakthrough in cryptanalysis. Information was also provided on current developments and innovations in the field of encryption and decryption, including Internet credit card security, military communication and anti-plagiarism software such as 'Turn It In'. Students were again required to answer questions about the podcast, reflect on the achievements of the mathematicians and to internalise that they themselves were following a similar investigative process in the tasks they were undertaking. This podcast was the precursor to the introduction of the topic for the inventions, developments, and change project.

The quiz linked to the inventions, developments and change Podcast, was again presented as part of a WebCT quiz, which allowed automatic marking and provided feedback on the students' responses. The quiz included specific questions that required students to analyse a graph providing data on the frequency of letters in the English alphabet. This task was in direct response to research carried out by the UAE University's College of Education, who concluded that a majority of science and mathematics students at secondary school level lacked the ability to interpret the information contained in graphs, pointing to a need for a shift from a passive culture of rote learning to an active culture of applied learning (UAE Ministry of Information and Culture, 2004, p. 2). Students were also provided with the opportunity to use JavaScript (Hannon, 2006) to code and decode messages using a mono-alphabetic substitution cipher.

An extension task was designed for those students who wished to further develop their mathematical understanding of frequency analysis. This task required students to use a formula enabled Microsoft Excel sheet and al-Kindi's method of frequency analysis to 'break' codes in order to find the original message. Coded messages, created using the JavaScript coding program, are pasted into the 'formula enabled' cell of the Excel sheet which generates a frequency list of the letters in the coded message.

Students then graphed the data and made a comparison to a graph of the expected frequency of letters in an uncoded message. By searching for patterns, students were able to find the encryption key. Once the key is located, student use the Java program to decrypt and decode the message.

Beyond the classroom task (BTC)

As with the previous topic-based project, students participate in a BTC task which sees them visit Ibn Battuta Mall in Jebel Ali, Dubai. The mall is named in honour of the historic Arab explorer, Ibn Battuta, who travelled extensively throughout the Islamic world. The themed shopping centre includes a permanent display of historical artefacts and presents information explaining the achievements of Islamic mathematicians and scientists. Students actively research information on both the historical people, as well as the innovations they discovered, before deciding on a topic associated with the inventions, developments and change project theme. The BTC task gives students the opportunity to reflect on specific mathematic and scientific achievements and the impact these achievements still have on the modern world. It also provides students with sufficient scaffolding to transfer the skills of conducting guided research to the next requirement of undertaking self-directed research and analysis.

Effectiveness of active teaching, active learning initiatives

A variety of data collection methods have been employed to measure the effectiveness of the RSandP course and gather attitudinal and evaluative feedback from learners and teachers. Feedback was collected using various instruments, including formal surveys (administered at the beginning and end of every semester), small group interviews, and informal verbal and written feedback.

Students reported that when they were required to solve the mathematics examples within the cooperative learning projects, they tended to feel more enjoyment for learning mathematics. They also indicated that they preferred instruction that provided practical applications of ‘real work mathematics’. The efforts to innovate and create new ways to teach students the interrelationships of mathematics, English, research skills, and technology were perceived by students to be one of the most rewarding activities in each respective project.

The most innovative success as described by the RSandP teaching team was the relationship across the instructional areas. The coordinated efforts by the mathematics, English, and computing teachers, was felt to have created an active learning environment that provided students with a unique opportunity to learn in a much broader context.

Conclusion

The successful implementation within RSandP, of active teaching, active learning strategies to teach mathematical skills and develop students’ mathematical thinking demonstrates the inherent strengths of cooperative learning which fosters student empowerment. Research findings indicate that students completing the RSandP course are better able to analyse problems and apply appropriate mathematical concepts and computing skills outside the classroom. Additionally, end-of-year findings suggest that students

become more self-directed as scaffolding is gradually removed during the iterative process throughout the year. Thus, student disorientation when employing mathematical skills outside the classroom context decreases, and the students' application of mathematical concepts within varying authentic contexts greatly expands.

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Students' perception of their readiness versus their true performance in pre-calculus algebra examination

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Abstract

In this paper we examine students' perception of their readiness on concepts and procedures required in the pre-calculus algebra major examination in comparison to their actual performance in the examination. The results indicate a high discrepancy between the two. The educational implications of these findings are also presented.

Introduction

King Fahd University of Petroleum and Minerals (KFUPM) is a highly selective university in the Kingdom of Saudi Arabia. Only the best students among the secondary school leavers in the Kingdom are admitted into KFUPM. Most of the students admitted are among the top ten per cent on their secondary school grade-point averages (GPA) and must have performed highly in the two university admission examinations. Therefore, students who have been admitted are considered to be the *crème de la crème* and are happy and proud to be among the best in the Kingdom.

Despite this rigorous selection procedure, admitted students have to undergo a one-year preparatory programme before they finally enrol in the undergraduate programme. One of the aims of the programme is to prepare students for English medium university life. As such, all subjects in the preparatory-year programme are taught in English. In the preparatory-year the students study mainly English, and a review of secondary school mathematics among other subjects.

However, students' performance in mathematics during this preparatory year is generally considered to be below expectations compared to their secondary school GPA. The exact reason for this discrepancy is not known. Nonetheless, many reasons have been hypothesized. These include a poor secondary school mathematics background, the high standard of the mathematics examinations in the preparatory-year, students' lack of motivation, a congested programme that gives no room for students to read and digest what they learn in class, and students' lack of seriousness towards their studies. Both students and teachers allude to these as some of the reasons why

students are not doing well. However, never in the history of the programme were the students given the opportunity to appraise their level of readiness for these examinations at the preparatory-year level. This study is an attempt to unveil students' perception of their understanding of the basic mathematics concepts and procedures that are a prerequisite for doing well in their examinations. Furthermore, we are interested in contrasting students' perception of readiness with their true performance in the examinations. Our hypothesis here is that there is a significant difference between students' perception of their understanding of basic concepts and procedures compared to their true performance in the preparatory-year examinations, which tested those concepts and procedures.

Literature review

Secondary school cumulative GPAs have been one of the most reliable way of predicting students future performance. It is widely used for students' admission and selection process. Recently, however, there have been some complaints regarding an escalation in secondary school marks. This is gradually eroding its reliability, causing a threat to genuine student assessment, and has had the tendency to make students have a false perception of their academic capabilities. As a result of these complaints, some researchers are suggesting some different criteria for a more valid selection measure (Bridgeman, Pollack and Burton 2004).

One approach that has been suggested is to collect students' self-reports, otherwise known as self-perception. If done properly, self-reports provide information that is invaluable in assessing student backgrounds and achievements. They also help in student placement, identifying high-risk and honours students; evaluating the quality of courses, services, and resources, initiating new programmes and evaluating existing programmes, and helping students make career decisions (Lebold, Budny and Ward, 1998; Brown, Lent and Larkin, 1989).

As a result, self-perception was part of the components of the Third International Mathematics and Science Study (TIMSS). TIMSS identified three measures of self-perception, which included how much students liked mathematics and science, how difficult they perceived the two subjects, and how well they thought they were doing in the two subjects (Shen, 2002). In fact, numerous studies have shown that there is a link between students' self-perception and both their behaviour and competence in academic achievement. In a study conducted by Bouffard, Markovits, Vezeau, Boisvert and Dumas (1998), it was found that the correlation between self-perception and performance was statistically significant, and higher among high IQ children than among low IQ children. However, often what students report with regards to mathematics and mathematics-related careers are often found to be at odds with their actual mathematics achievements (Shen and Talavera, 2003). Advancing the analysis of the TIMSS data, Shen and Talavera (2003) found that within-country data generally showed a positive relationship between student achievement and self-perceived competence in mathematics and science. However, when they examined this same relationship between countries, they found the opposite relationship. That is to say, countries with a high proportion of students perceiving mathematics and science as being easy performed poorly on the TIMSS tests and those with a lower proportion perceiving them easy performed

highly. Shen (2002) noted that this pattern is consistent in both mathematics and science at grades 3, 4, 7 and 8, as well as in the previous TIMSS examinations. The most plausible reason for this discrepancy according to Shen and Talavera (2002) is that the pattern in the results may reflect low academic expectations and standards in low performing countries and high academic expectations and standards in high performing countries. It is our belief that similar results may be obtained if a similar analysis were to be done between students' secondary school grades in the Kingdom of Saudi Arabia and their performance in universities like KFUPM.

Method

The participants in this study were native Arab male students with an average age of 18 years. These newly-admitted students are largely considered as the *crème de la crème* of Saudi graduates from Arabic medium secondary schools, and are in their first semester of the preparatory year programme at KFUPM.

Data

The data for this study consist of a survey conducted on students' perception of their preparedness on the concepts and procedures that are tested in the examinations for a pre-calculus algebra course. This survey consisted of all the concepts and procedures that were needed for the examinations. The second set of data was the students' actual grades in the two examinations (first major and mid-term).

Procedure

The survey was given to the students a day before the examinations. Students were asked to rate their level of understanding of the concepts, and their level of competence in knowing how to use the procedures to solve problems. The survey is a Likert-type scale ranging from 'Strongly agree' to 'Strongly disagree'. Throughout the analyses in this paper, 'Strongly agree' was treated as 1 and 'Strongly disagree' was treated as 5. Thus, lower values signify that students strongly agree they are prepared on materials covered by the examinations.

Result and discussion

The issue of students' self-perception and their actual level of readiness in a course was studied with a self-reported survey and actual performance in two examinations of MATH 001. The results of the study are summarised in Tables 1 through 5 in this section.

Table 1 provides summary information of the survey instrument used to gather students' self-perception on their readiness to take the examinations. Right before Exam 1 and the mid-term examination, a survey was given to the students with the aim of measuring their level of preparedness on concepts and procedures related to the topics to be examined. As shown in Table 1, there was a total of 45 questions on the Exam 1 readiness survey while there were 66 for the mid-term readiness survey. Table 1 also shows the mean, the standard deviation, and the alpha reliability ($r_{xx'}$) of the scores for each of the survey scale. With the alpha reliability index of at least 0.93, all the scales in the survey are highly reliable. To ease interpretation, Table 1 also provides the mean

and standard deviation of the items on each scale. The item mean provides, on average, the level of readiness students report prior to their examinations. Since the Likert scale for the survey goes from ‘Strongly agree’ through to ‘Strongly disagree’ with 1 being ‘Strongly agree’ while 5 being the exact opposite, the average value of readiness reported by the students is somewhere between agree and strongly agree. That is, students generally view themselves as well-prepared with the course materials prior to the actual examinations.

Instrument	Scale	Item	Scale Mean	SD	$r_{xx'}$	Item Mean	SD
Exam 1 readiness	Concepts	25	40.092	12.857	0.933	1.604	0.514
	Procedure	20	35.656	11.231	0.934	1.783	0.562
	Total	45	75.754	22.045	0.958	1.683	0.490
Mid-term examination readiness	Concepts	35	60.340	20.843	0.965	1.724	0.596
	Procedure	31	58.536	19.459	0.963	1.888	0.628
	Total	66	115.413	40.484	0.983	1.749	0.613

Table 1: Student preparedness on mathematics concepts and procedures as measured by a Likert-type survey.

Students’ performance on these examinations are also summarised and reported. In particular, Table 2 provides total score mean, standard deviation, and alpha reliability ($r_{xx'}$) for the two examinations.

Test	N	Score		$r_{xx'}$	Item correct	
		Mean	SD		Mean	SD
Exam 1	15	7.037	2.975	0.671	0.469	0.198
Mid-term	25	12.756	4.880	0.792	0.510	0.195

Table 2: Student performance on course examinations.

The alpha reliability index are reasonable for tests that are as short as those reported in the table. The mean and standard deviation for the item correct are also reported in the table. The mean item correct shows that only about forty-seven per cent of the students answered the items correctly on the first examination and around fifty-one per cent of the students answered the items correctly on the mid-term examination. This is in sharp contrast to students’ self-reported levels of preparedness uncovered by results summarised in Table 1.

To study closely the students’ readiness on the conceptual and procedural questions of the tests, test questions were categorised by their requirement for knowledge of concepts only, procedures only, an equal weighting of concepts and procedures, or a heavier weighting on the procedures.

Table 3 provides a summary of the analyses. In particular, Table 3 provides the number of items, the score means and standard deviations, and the item correct means and standard deviations for all items measuring the same type of scale. It can be seen

that there are generally more test items measuring the procedure with more emphasis than concepts only, procedure only, or both equally on both examinations. For the first examination, items measuring concepts and procedure equally appear to have the lesser proportion of students answering correctly followed by those measuring concepts only, procedure only and more heavily procedural. For the mid-term examination, items measuring concept only and procedure only appear to have more students answering correctly than those measuring concept and procedures equally or those measuring procedures more densely.

Test	Scale measured	Score			Item correct	
		item	Mean	SD	Mean	SD
Exam 1	Concept only	3	1.244	0.924	0.415	0.308
	Procedure only	2	0.902	0.730	0.451	0.365
	Concept and procedure	3	1.159	0.881	0.386	0.294
	More procedure	7	3.732	1.508	0.533	0.215
Mid-term	Concept only	2	1.305	0.796	0.652	0.398
	Procedure only	5	3.122	1.328	0.624	0.266
	Concept and procedure	6	2.634	1.528	0.439	0.255
	More procedure	12	5.695	2.581	0.475	0.215

Table 3: Student performance on course examinations by scale requirements of the test items.

Tables 4 and 5 show the proportion of students who ended up answering the examination questions correctly versus those who reported that they were ready for the tests. The confidence intervals for the proportion of students answering the questions correctly are also reported in the tables. In both tables, anytime the proportion-ready value was outside the interval by exceeding the upper confidence limit (UCL), the proportion-ready value was written in a bold-faced font. If the opposite occurred, that is if the proportion-ready value was lower than the lower confidence limit (LCL), the proportion-ready value was italicised. Otherwise, the same type-face as the rest of the table values was used.

It is apparent in both tables that more students reported they were ready compared to those who actually answered correctly for almost all the examination questions. And this is true for the two examinations. Only in one instance (Item 6 on the mid-term), the opposite was the case. In addition, the differences between the proportion of students who reported that they were completely ready for the examinations and those who answered the test items correctly is found to be statistically significant. This is true for more than 80 per cent of all examinations items.

Conclusion

In this study we investigated students' perception of their level of examination preparedness with regard to mathematics concepts and procedures in contrast with their

	Prop correct	95% CI		Prop ready
		LCL	UCL	
M1	0.488	0.377	0.598	0.931
M2	0.512	0.402	0.623	0.747
M3	0.561	0.451	0.671	0.890
M4	0.354	0.248	0.459	0.821
M5	0.768	0.675	0.862	0.861
M6	0.390	0.282	0.498	0.887
M7	0.512	0.402	0.623	0.882
M8	0.280	0.181	0.380	0.724
M9	0.756	0.661	0.851	0.827
M10	0.744	0.647	0.840	0.798
M11	0.317	0.214	0.420	0.771
M12	0.134	0.059	0.209	0.747
M13	0.341	0.237	0.446	0.914
M14	0.415	0.306	0.524	0.897
M15	0.463	0.353	0.574	0.852

Table 4: Proportion of students answering Exam 1 items correctly versus the proportion who reported they were ready.

actual performance in the examinations. The survey results indicated that the students thought they were fully ready for the examinations, however, the examination results indicated the contrary. This shows that either the students overestimated their level of understanding and preparedness for the examinations, or under-rated the level of the examinations. In either case, the students need to know their true level of academic standing and be realistic in order to prepare well for any examination. If a student does not know, and he does not know that he does not know, then there is a tendency that the teacher and students will not achieve their respective goals. On the other hand, if the student does not know and he knows that he does not know, then there is a chance for corrective actions such as counselling, improvement, and working harder to achieve learning goals. Therefore, teachers should be aware of this, and also make students realistically aware of their true academic standing.

	Prop correct	95% CI		Prop ready
		LCL	UCL	
M1	0.415	0.306	0.524	0.682
M2	0.427	0.317	0.536	0.714
M3	0.378	0.271	0.485	0.743
M4	0.866	0.791	0.941	0.799
M5	0.329	0.225	0.433	0.767
M6	0.756	0.661	0.851	0.650
M7	0.634	0.528	0.741	0.809
M8	0.598	0.489	0.706	0.446
M9	0.488	0.377	0.598	0.750
M10	0.622	0.515	0.729	0.765
M11	0.561	0.451	0.671	0.774
M12	0.573	0.464	0.683	0.705
M13	0.646	0.541	0.752	0.824
M14	0.549	0.439	0.659	0.682
M15	0.390	0.282	0.498	0.775
M16	0.622	0.515	0.729	0.779
M17	0.646	0.541	0.752	0.727
M18	0.463	0.353	0.574	0.728
M19	0.280	0.181	0.380	0.739
M20	0.610	0.502	0.718	0.690
M21	0.341	0.237	0.446	0.750
M22	0.244	0.149	0.339	0.775
M23	0.341	0.237	0.446	0.681
M24	0.659	0.554	0.763	0.828
M25	0.317	0.214	0.420	0.750

Table 5: Proportion of students answering mid-term examination items correctly versus proportion who reported they were ready.

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Geometric interpretation of the Gauss elimination method for linear systems

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Abstract

The geometric interpretation of the solution set of a system of linear equations as the intersection of lines or planes depends on whether two or three variables are known. In this paper, through a modification of the representation equation to line or plane, a geometric interpretation of the Gauss elimination method for solving a linear system is presented.

Introduction

In this paper, I present a geometric interpretation of the Gauss elimination method. This interpretation is accessible at the college algebra level as covered by college algebra textbooks (see, e.g., Barker, 2005). The geometric representation of a system of two equations in two variables is known. Given a system

$$a_1x + b_1y = c_1 \quad (1)$$

$$a_2x + b_2y = c_2, \quad (2)$$

each equation represents a line in the plane, $\mathcal{L}_1$ for equation (1) and $\mathcal{L}_2$ for equation (2). The solution set of the system represents the intersection of the two lines. Similarly, given a system of three equations in three variables

$$a_1x + b_1y + c_1z = d_1 \quad (3)$$

$$a_2x + b_2y + c_2z = d_2 \quad (4)$$

$$a_3x + b_3y + c_3z = d_3, \quad (5)$$

every equation represents a plane in space, and the solutions are the points of intersection of the three planes.

The Gauss elimination method consists of a succession of two types of operations: (i) replacing a given equation by one non-zero multiple, and (ii) replacing an equation by the sum of two equations. Because the crucial step is to give geometric meaning to these two operations, we find that the representation of a linear equation as either a line or plane is not adequate.

The problem

The addition of two linear equations represented by two lines $\mathcal{L}_1$ and $\mathcal{L}_2$ gives a third equation represented by $\mathcal{L}_3$. How is the third line related geometrically to the first two lines? Notice that if we replace one equation by an equivalent equation, that is if we multiply it by a non-zero scalar and redo the addition, we obtain a different equation not equivalent to the previous one and represented by a line $\mathcal{L}_4$ which is different from $\mathcal{L}_3$. So we cannot get $\mathcal{L}_3$ from a knowledge of lines $\mathcal{L}_1$ and $\mathcal{L}_2$ only. To resolve this problem, we modify our representation for the equation of a line.

New representation

Given an equation $ax + by = c$, we now represent it by the line $\mathcal{L}$ which it represents and the vector $V = \langle a, b \rangle$ which is orthogonal to $\mathcal{L}$.

Geometric interpretation of addition of linear equations

With this view, line $\mathcal{L}_3$ which represents the sum of the two equations (1) and (2) is the line which passes through the intersection point of the lines $\mathcal{L}_1$ and $\mathcal{L}_2$ and with orthogonal vector $V_3 = V_1 + V_2$, the sum of the orthogonal vectors V_1 and V_2 of the lines $\mathcal{L}_1$ and $\mathcal{L}_2$.

Geometric interpretation of scalar multiplication

In the old representation, two equivalent equations represented the same line. Hence, given an equation representing a line, there is no way one can recapture the exact equation from the line (with the exact coefficients). In the new representation, since two equivalent equations are multiples of each other,

$$\begin{aligned} ax + by &= c \\ kax + kby &= kc, \end{aligned}$$

the second line has its orthogonal vector dilated which distinguishes the two representations $(\mathcal{L}, V)$ and $(\mathcal{L}, kV)$.

Simple elimination method

This method is used in simple cases. Consider the following example

$$\begin{cases} 5x + 3y = 7 \\ 3x - 2y = 8. \end{cases}$$

On performing elementary row operations one has

$$\begin{aligned} \begin{matrix} 2R_1 \\ 3R_2 \end{matrix} &\rightarrow \begin{cases} 10x + 6y = 14 \\ 9x - 6y = 24 \end{cases} \\ R_1 + R_2 &\rightarrow \begin{cases} 10x + 6y = 14 \\ 19x = 38. \end{cases} \end{aligned}$$

The vectors are dilated so that their sum is a horizontal vector (we could have chosen to make it vertical).

$$R_2/19 \rightarrow \begin{cases} 10x + 6y = 14 \\ x = 2. \end{cases}$$

The back substitution gives $y = -1$ with a final solution of $(2, -1)$.

Geometric interpretation of the Gauss elimination method

This is a systematic method which contains some normalising steps. Consider the following example.

$$\begin{aligned} & \begin{cases} 3x + 5y = 9 \\ 2x - 3y = -13 \end{cases} \\ R_1/3 & \rightarrow \begin{cases} x + 5y/3 = 3 \\ 2x - 3y = -13. \end{cases} \end{aligned}$$

The vector $V_1 = \langle 3, 5 \rangle$ is shrunk so that the first component is 1, namely $V'_1 = \langle 1, 5/3 \rangle$.

$$\begin{aligned} -R_1/2 & \rightarrow \begin{cases} x + 5y/3 = 3 \\ x - 3y/2 = -13/2 \end{cases} \\ -R_1 + R_2 & \rightarrow \begin{cases} x + 5y/3 = 3 \\ 0x + 19y/6 = 19/2 \end{cases} \\ 6R_2/19 & \rightarrow \begin{cases} x + 5y/3 = 3 \\ y = 3. \end{cases} \end{aligned}$$

The vector $V_2 = \langle 2, -3 \rangle$ is shrunk so that the first component is 1, namely $V'_2 = \langle 1, 5/3 \rangle$.

The line $\langle \mathcal{L}_2, V'_2 \rangle$ is replaced by a line whose vector is the sum of the vectors of the first two lines, so that V_3 is vertical and hence the line $\mathcal{L}_3$ is horizontal. For computation purposes the second component of V_3 is normalised.

In a related method, sometimes called the Gauss–Jordan method, continuing to perform elementary row operations gives from the last step

$$R_1 - 5R_2/3 \rightarrow \begin{cases} x + 0y = -2 \\ y = 3. \end{cases}$$

The first line is replaced by a line whose vector is the sum of first vector and a multiple of the second vector so that the new vector is horizontal. The solution is easy to see from the graph by noting the x -intercept of the first line and the y -intercept of the second.

Summary

Essentially, the Gauss elimination method dilates the orthogonal vectors of the two lines so that their sum is a vertical vector. It then replaces the second line at the point of intersection by a line whose orthogonal vector is the new vector. For the Gauss–Jordan method, it precedes to dilate the two new vectors so that their sum is a horizontal vector. Note that the new representation can also be adapted to systems of three linear equations in three variables.

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Using multiple representations to promote understanding in the learning of mathematics

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Abstract

Numerous researchers advocate the use of multiple representational approaches to teaching and learning to develop a greater understanding of mathematics. While the traditional perspective of the multiple representation of mathematical ideas has centred ‘itself’ around the symbolic, graphical, and numerical presentation of ideas and scenarios, it is worth noting that there are other ‘competing’ representational systems such as estimation and calculation; and contextualisation and abstraction, modelling or determination which may be offered dialectically to extend meaning and understanding through the process of contrast. In the case of students studying mathematics in a foreign language (in this case English), the use of multiple representational presentations of ideas and data is highly desirable. This paper provides teachers with the minds-on experience of doing mathematics within a multi-representational framework. The chosen topic, solving quadratic equations (graphically, symbolically and numerically), is designed to connect with teachers at all levels of mathematics, and the ethos and process of the examples described should be easily transferable to other work. A variety of techniques and technologies including computer graphics, the Internet, graphics calculators and emulators, and interactive teaching strategies to negotiate a curriculum that connects the algorithmic and symbolic, to the graphical, to the numeric, to real world applications, are all used to illustrate how one goes about finding the real and the imaginary solutions to quadratic equations.

Introduction

As the old proverb goes ‘a nod is as good as a wink to a blind horse’. Have you ever reflected upon what you are doing when you teach mathematics? Are you inculcating in your students the same love and appreciation for mathematics that you have, yourself? Are you exposing them to the trepidation and the pleasure of solving challenging problems? Guiding them through a maze of data and clues in which they get to select and test a range of ideas, techniques and technologies. Do you have your students thinking strategically, connecting a wide variety of mathematical and practical ideas, sharing their obstructions, frustrations and solution pathways; and maybe even talking about their thinking? Or are you too busy? Is your teaching time spent presenting examples,

ideas, samples and tricks that will get your students safely through the next examination, hopefully with a grade that will do you both proud? Probably the latter, if you are a typical mathematics teacher working in a typical institution, for a typical education board, in a typical country, anywhere in the world.

In an age when the influence of ‘high stakes’ examinations has annealed rather than diminished, it would be professional suicide for any teacher to ignore examination outcomes and focus instead on educational reform. Until governments and educational leaders remove the ‘strings’ of teacher performance and accountability connected to these activities, any board-driven attempts at reform will be taken as rhetoric, and teachers will continue to teach in the manner that they themselves were taught. The unfortunate thing about this response is that an overwhelming body of evidence indicates that reform in mathematics education is necessary and that students would benefit greatly in the medium to long term from its implementation. For example, the skills developed in a cooperative problem-solving activity are more applicable and far more sustainable than the memorisation of an algorithm most likely forgotten soon after it is applied in an examination. So what can we do? How do we navigate the pragmatic pathway between ‘reform’ and ‘conform’?

Resolution

One strategy employed in lower and middle school mathematics classes and some second language foundation programmes (AlSuwaidi, 2001) has been the establishment of collaborative (student) problem-solving teams in which the teacher orbits and alludes, rather than centralises and advises. Under the right conditions this has been an effective strategy, but in senior secondary and at tertiary levels where syllabi are full, much of this has been encouraged ‘off-campus’ so that teachers can get through a large amount of ‘content’ during lesson times.

Another strategy more applicable to all levels has been the use of technology to provide students with ‘multiple learning perspectives’. Technology has allowed students to interact: to see, hear, feel, experience situations and ideas from a variety of perspectives and interpretations. This has made the learning experience far more relevant and applicable to the students’ ‘real-life’ world, (Aikenhead, 2001; Duit and Confrey, 1996) than would otherwise be the case.

As another old adage says ‘a picture is worth a thousand words’ and is hardly a new idea. Electronic media (videos, CDs, DVDs, podcasts, etc.) are standard teaching resources in most institutions. Mathematics teachers have had fewer uses for media but have used their own techniques of visualisation to teach geometry and calculus, for example, by means of proofs and derivations from which students view a ‘bigger picture’ and get to see why certain observations were made and from where conclusions were drawn.

As technology has progressed, opportunities to present ideas in this manner have multiplied, and as I have shown in previous encounters (Ward, 2005), it is now relatively easy to develop or download still and animated demonstrations of mathematical behaviours or concepts. One example of this was the use of Geometer’s Sketchpad to demonstrate pictorially and graphically the connection between physical dimensions and the algorithms for their calculation and analyses. Another was the use and adap-

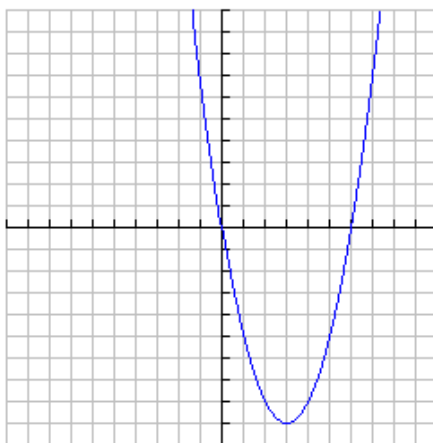
tation of web-based animations to make connections in trigonometry between circular and wave-like motion (Ward, 2006).

A third example which I intend to build upon the ideas introduced in last year's presentation (Ward, 2006) is the use of a graphics calculator as a means of decentralising teaching activity and providing the opportunity for the learning of mathematics via multiple perspectives. As an example of this I shall describe how one can use a graphics calculator to connect conceptually between the real and imaginary roots of quadratic equations. While this choice may seem a little narrow or dry, I can assure that it is not, and that the use of a graphics calculator makes it an interesting and challenging experience.

Applying a solution

As an example of the type of exercise I typically get students to work through is the following (at the conference this exercise was performed as a workshop with delegates).

1. Graph the quadratic function $y = x^2 - 6x$.
2. Use the calculator functions to find the zeros and the vertex of the parabola.
 - (a) Label these on the diagram provided.



- (b) Write the equation of the parabola in vertex form $y = a(x - h)^2 + k$.
3. Repeat steps 1 and 2 for the functions $y = x^2 - 6x + 5$ and $y = x^2 - 6x + 7$.
4. Using the general (monic) quadratic function in vertex form (i.e., $y = (x - h)^2 + k$) derive a formula that connects the vertex to the zero's. Test this formula on the function $y = x^2 - 6x + 9$.
5. Derive a similar formula for the general (non-monic) quadratic function $y = (x - h)^2 + k$.

6. Test this formula on a function of your own choosing.
7. Apply the process and your ‘findings’ to the following quadratic functions whose zeros are non-real.

$$(i) y = x^2 - 6x + 13 \quad (ii) y = x^2 - 6x + 10 \quad (iii) y = 2x^2 - 12x + 22.$$

Discussion

- Q1** Could you apply a similar process to higher order equations? Explain.
- Q2** How could you apply this overall process of visual investigation in other mathematical areas?

Conclusion

When we teach quadratic functions there is a tendency to demonstrate the three cases for the discriminant ($\Delta = b^2 - 4ac$) to our students and relate these to a set of ‘pictures’ indicating two real and distinct roots, two real and identical roots (or one real root); and no real roots. We then apply this to determining the number of solutions to a given quadratic equation. Later, when teaching polynomials (often as a separate unit) teachers sometimes introduce imaginary roots in an attempt to connect the degree of a polynomial to the maximum number of roots. Students usually take these to be two disconnected ‘events’. They often memorise and apply both sets of rules without making the connection.

The approach described here using multiple perspectives – graphical + symbolic + numeric; and/or collaborative/interactive makes the connection between both ‘units’ of work. In addition to allowing students to discover the relationships (including a geometric connection) themselves, it encourages students to make and test conjectures. It also allows them to ask their own and further questions, and diversify if they so desire.

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Using technology to forge the link between formal mathematical definitions and related problem-solving techniques

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Abstract

Many students enrolled on engineering programmes requiring a traditional calculus sequence find it difficult to appreciate the relationship between conceptual definitions and their application in performing calculations. Typical examples include the link between the ε - δ definition of the limit and finding specific limits; or the link between differentials and solving practical problems involving error analysis. In this paper we describe an example showing how technology and computer algebra systems can help the student bridge the gap between the concept of the Riemann sum and the definite integral.

Introduction

Students who are non-mathematics majors and who are, for the first time, taking a typical introductory calculus course as part of the usual calculus sequence, often have difficulty comprehending the link between the Riemann sum and the definition of the definite integral. The student usually encounters these two mathematical objects via the following definitions.

Definition of the Riemann sum

Let $\{x_0, x_1, \dots, x_n\}$ be a (regular) partition of the interval $[a, b]$, with $\Delta x = x_i - x_{i-1} = (b - a)/n$, for all i . Choose points $c_1, c_2, \dots, c_n$, where c_i is any point (called an evaluation point) in the subinterval $[x_{i-1}, x_i]$ for $i = 1, 2, \dots, n$. The Riemann sum for the partition with its evaluation points is the sum $\sum_{i=1}^n f(c_i) \Delta x$.

Definition of the definite integral

The definite integral of the function $f(x)$ from a to b is

$$\int_a^b f(x) dx = \lim_{n \rightarrow \infty} \sum_{i=1}^n f(c_i) \Delta x,$$

where f is any function defined on $[a, b]$ for which the limit exists.

The typical ‘route’ traversed by the student when first meeting these definitions is:

1. Definition of the Riemann sum.
2. Examples of Riemann sums being used to *approximate the area* under a continuous, non-negative function $f(x)$ over an interval $[a, b]$ using a regular partition, a finite number of n subintervals (or approximating rectangles), and with the evaluation points being either left or right end-points, or mid-points.
3. The statement of another linking definition, that of the area A under a curve $y = f(x)$ (when f is continuous and non-negative on $[a, b]$), as the limit of the Riemann sum as the number of subintervals n tends to infinity.

$$A = \lim_{n \rightarrow \infty} \sum_{i=1}^n f(c_i) \Delta x.$$

Aside: Although a proof is not given, the student is usually informed that the aforementioned limit is independent of any choice of evaluation points.

4. Definition of the definite integral.
5. It is then noted that when $y = f(x)$ is a continuous and non-negative curve on $[a, b]$,

$$\int_a^b f(x) dx = \text{the area under the curve on } [a, b].$$

6. Examples of computing the exact areas under non-negative curves as the limit of the corresponding Riemann sum.
7. Returning to the definition of the definite integral, but this time considering the situation where $f(x)$ could be negative, i.e. introducing the concept of the *signed area*.
8. Examples of signed areas being computed as the limit of Riemann sums.

Before the digital age

During the ‘handraulic’ pencil and paper era, prior to today’s ‘information age’ of readily available software tools such as computer algebra systems (CAS), stored on either desktops or portable devices like the Texas Instruments TI-89 graphics calculator, and

information technology (IT) presentation tools such as PowerPoint or Java applets, the student's 'route' through the above nexus of related mathematical concepts involved grappling with aspects that some educators might consider today to be hindrances or drawbacks. Some of these are outlined below.

The static nature of the presentation

The larger the number of rectangles employed, the better the approximation of the area under a given curve. The visual evidence available to the student in support of this concept was restricted to the relatively small number of given textbook diagrams accompanying the examples. For the student to generate additional graphical illustrations for his or herself, was time intensive.

The set of curves available for student's consideration was limited

The function set used in the hand computations of Riemann sums was, out of practical necessity, limited to simple polynomial functions.

The number of approximating rectangles had to be comparatively small

Typically, $n \leq 10$. Values larger than this tended to involve computations that took too much time. This restricted the student in examining the evidence that the Riemann sums converge to a value.

The prerequisite status of summation formulae in the topic sequence

Prior to doing explicit calculations of Riemann sums involving n rectangles, the student had to have been introduced to summation formulae for sums of powers of positive integers. (Satisfactory coverage of this topic might also have included the principle of mathematical induction). Of itself, this was not a problem, but it did restrict the sequencing of topics, and drew the focus away from the concept of the Riemann sum.

The issue of motivation

It is arguably the case that the advent of IT mathematical presentation tools has made it easier to engage and increase the appreciation of those students who are not majoring in mathematics. Prior to the digital era, the static imagery coupled with the pencil and paper computations contributed to a larger number of students (especially non-science majors) becoming frustrated and bored. Also, it was not a simple task to satisfy the students' reasonable demands for realistic applications of the topics to be considered.

Incorporating the technology

In this section we describe an approach we have used in our teaching to help clarify the link between Riemann sums and the definite integral. The students were first-year engineering students at The Petroleum Institute in Abu Dhabi. Technology is employed as part of an effort to enhance the students' exploration of the material, and to ameliorate the drawbacks listed in the previous section.

As a lead into the description of the authors' Riemann sum exposition, the background of the student target audience is mentioned. The average student member has used a scientific calculator during secondary school, before entering The Petroleum Institute. Prior to commencing their undergraduate studies, the majority of the students enter into the institute's Foundation Program. During their Foundation year, they make extensive use of the Texas Instrument TI-84 graphics calculator in their pre-calculus

courses. Upon entry into the undergraduate programme, each student is issued with a TI-89 CAS-enabled graphics calculator.

At the expository stage, before the students individually work through set calculation problems, they see an animated Excel presentation (developed in-house) of Riemann sums. Following the class presentation, the software used is made available online¹ to all students who are encouraged to explore it at their own pace. The student has available a set of functions to choose from, and the options of left and right end-points, or mid-points, can be selected. Also, a 'slider bar' controls the number of approximating rectangles. Worked examples used to support the underlying concepts and to show how the TI-89 calculator can be utilised to facilitate computation and to explore convergence are then presented. As an illustration of the type of examples we have our students explore, two examples will be presented.

Example 1

Use four rectangles to approximate the area under the curve $y = x^2$ over the interval $[0, 1]$ using (a) right end-points, (b) left end-points, and (c) mid-points.

Solution outline

(a) Let $f(x) = x^2$. The width of each rectangle is

$$\Delta x = \frac{1 - 0}{4} = \frac{1}{4},$$

while the evaluation points are

$$c_1 = 0 + 1 \cdot \Delta x = \frac{1}{4}, \quad c_2 = 0 + 2 \cdot \Delta x = \frac{1}{2}, \quad c_3 = 0 + 3 \cdot \Delta x = \frac{3}{4}, \quad c_4 = 0 + 4 \cdot \Delta x = 1.$$

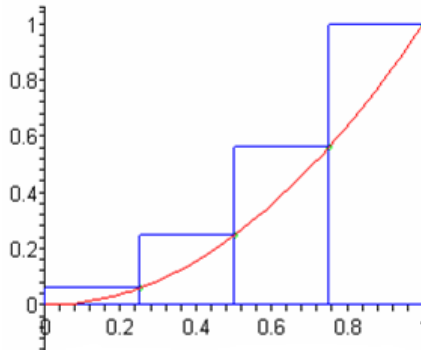


Figure 1: The four rectangles formed 'under' the curve $y = x^2$ when right end-points are used.

So

$$R_4 = \sum_{k=1}^4 f(c_k) \Delta x$$

¹The course management system used at The Petroleum Institute for this purpose is Moodle.

$$\begin{aligned}
&= [f(c_1) + f(c_2) + f(c_3) + f(c_4)]\Delta x \\
&= [f(1/4) + f(1/2) + f(3/4) + f(1)] \frac{1}{4} \\
&= \left[\left(\frac{1}{4}\right)^2 + \left(\frac{1}{2}\right)^2 + \left(\frac{3}{4}\right)^2 + (1)^2 \right] \frac{1}{4} \\
&= \frac{15}{32} \\
&= 0.46875.
\end{aligned}$$

Here R_4 indicates that four rectangles with right end-points are being used. The students are then shown how the TI-89 can be used in the calculation. Basic keystrokes used on the TI-89 are given throughout the text using a computer font. For those unfamiliar with the basic operation of the TI-89, one is referred to the *Texas Instruments TI-89 Guidebook* (Texas Instruments, 2000).

Function set up: $f(x) = x^2$ (TI-89 syntax: x^2 ST0> $f(x)$). Rectangle width: $\Delta x = 1/4$ (1/4 ST0> dx). The evaluation points corresponding to right end-points $x_k = 0 + k \cdot \Delta x$ ($k \cdot dx$ ST0> $x(k)$). The Riemann sum: $\sum_{k=1}^4 f(c_k) \Delta x$ (F3 $\rightarrow$ 4: $\Sigma \rightarrow \Sigma(f(x(k)) \cdot dx, k, 1, 4)$) gives a result of $15/32$.

In part (b) left end-points are considered, and the analytic calculation is gone through first. Then, at the TI-89 stage the students are alerted to the fact that only a minor amount of editing needs to be done to change from right end-points to left end-points. Editing $k \cdot dx$ ST0> $x(k)$ to read $(k-1) \cdot dx$ ST0> $x(k)$, the rest of the pre-entered command lines remain unaltered. The TI-89 yields the left end-point result (L_4): $7/32$.

In part (c) the TI-89 handles the mid-point case via the following syntax: $(k-1/2) \cdot dx$ ST0> $x(k)$ to produce the mid-point result (M_4): $21/64$. The students are then led through Example 2, which tackles the problem from the standpoint of using an arbitrary number of rectangles n to find the approximation of the area under the curve.

Example 2

Use n rectangles to approximate the area under the curve $y = x^2$ over the interval $[0, 1]$ using (a) right end-points, (b) left end-points, and (c) mid-points.

Solution outline

(a) Let $f(x) = x^2$. The width of each rectangle is

$$\Delta x = \frac{1-0}{n} = \frac{1}{n}.$$

There are now n evaluation points

$$\begin{aligned}
c_1 &= 0 + 1 \cdot \Delta x \\
c_2 &= 0 + 2 \cdot \Delta x \\
c_3 &= 0 + 3 \cdot \Delta x \\
&\vdots
\end{aligned}$$

$$\begin{aligned}c_{n-1} &= 0 + (n-1) \cdot \Delta x \\c_n &= 0 + n \cdot \Delta x\end{aligned}$$

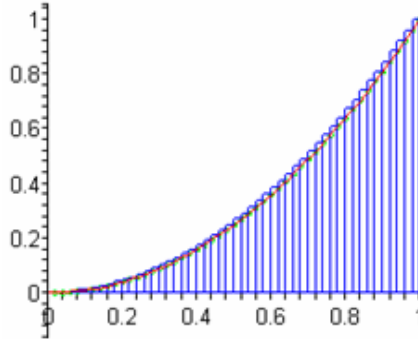


Figure 2: The n rectangles formed under the curve $y = x^2$ when right end-points are used.

In this case the Riemann sum is given by

$$R_n = \sum_{k=1}^n f(c_k) \Delta x = (f(c_1) + f(c_2) + \dots + f(c_{n-1}) + f(c_n)) \Delta x.$$

Here R_n indicates that n rectangles with right end-points are being used. This is found to be a useful place for the TI-89 to enter into the calculation. First some editing of the command lines is required. Editing $1/4 \text{ STO} > dx$ to read $1/n \text{ STO} > dx$, since right end-points are used, we again use $\text{STO} >$ to store the data about the evaluation points. Then we can proceed to compute the sum for n approximating rectangles simply by editing $\sum (f(x(k)) * dx, k, 1, 4)$ to read $\sum (f(x(k)) * dx, k, 1, n)$. The calculator gives the result

$$\frac{(n+1)(2n+1)}{6n^2},$$

which is stored in the calculator as $R(n)$.

In part (b) the approximate area is computed using left end-points, and to store the new evaluation point data simply involves $(k-1) * dx \text{ STO} > x(k)$. The calculator gives the result

$$\frac{2n^2 - 3n + 1}{6n^2},$$

which is stored in the calculator as $L(n)$.

In part (c) the approximate area is computed using mid-points. The evaluation point data is stored as $(k-1/2) * dx \text{ STO} > x(k)$. This time the calculator computes $\sum (f(x(k)) * dx, k, 1, n)$ to be

$$\frac{4n^2 - 1}{12n^2},$$

which is stored as $M(n)$.

Following on from this example, the students are assigned the in-class calculator task of completing a table in order to explore the convergence of the left and right end-point sums (see Table 1).

In-class task 1

Having gone through each step of Example 2 for themselves, the students will have stored on their calculators $L(n)$, $R(n)$ and $M(n)$. It does not take long for them to produce a table demonstrating the evidence that the three sets of numbers converge to a common limit of (approximately) 0.333333.

n	$L(n)$	$M(n)$	$R(n)$
10	0.285	0.3325	0.385
50	0.3234	0.3333	0.3434
100	0.32835	0.333325	0.33835
500	0.332334	0.333333	0.334334
1000	0.332834	0.333333	0.333834
5000	0.333233	0.333333	0.333433
10^6	0.333333	0.333333	0.333334

Table 1: Convergence of Riemann sums using left end-points ($L(n)$), mid-points ($M(n)$), and right end-points ($R(n)$).

A number of students will notice that the different evaluation point formulae tend to the common limit at different rates. Further, they will correctly extrapolate from the table the exact area under the curve i.e. $0.\dot{3} = 1/3$. To confirm their extrapolation, the students use their calculators to directly evaluate the limits

$$\lim_{n \rightarrow \infty} L(n) = \lim_{n \rightarrow \infty} M(n) = \lim_{n \rightarrow \infty} R(n) = \frac{1}{3}.$$

The TI-89 commands for doing this are $\text{F3} \rightarrow 3: \text{limit} \rightarrow \text{limit}(L(n), n, \infty)$.

After several tasks involving finding Riemann sums for fixed and arbitrary values of n , as well as calculations of areas under curves as limits have been undertaken by the group, the following in-class task is assigned. Its purpose is to emphasize to the student that every technology has its limits, and the TI-89 is no exception.

In-class task 2

Use mid-points to find the exact area under the curve $y = \cos(x)$ over the interval $[0, \pi/2]$ as a limit.

Solution outline

Performing the calculation with mid-points using the TI-89 gives

$$M_n = \frac{\sum_{k=1}^n \cos\left(\frac{k\pi}{2n} - \frac{\pi}{4n}\right)\pi}{2n}.$$

Students note the fact that the TI-89 has not been able to evaluate the sum as a formula in n . When the calculator attempts to find the limit $\lim_{n \rightarrow \infty} M_n$ it only presents

the unhelpful result

$$\lim_{n \rightarrow \infty} \frac{\sum_{k=1}^n \cos\left(\frac{k\pi}{2n} - \frac{\pi}{4n}\right)\pi}{2n}.$$

Although, in this case, the TI-89 is not able to find the exact area as a limit of Riemann sums, the students quickly discover that it is able to compute satisfactory approximations such as $M_{20} = 1.00026$. This is an appropriate place to conclude the introduction of Riemann sums, and to alert the students to the existence of more powerful CAS packages such as Maple or Mathematica.

Summary

The use of technology in the mathematics classroom is one way the link between formal mathematical definitions and actual calculations based on these definitions can help breach the gap between the two in the minds of the student. In this paper an example involving the connection between the concept of the Riemann sum to the definite integral using a CAS-enabled TI-89 graphics calculator has been described. It is hoped that through the tasks we have students complete they will come to see with greater understanding the connection between a highly formalised definition on the one hand and how it relates to actual computation on the other hand.

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Web technologies for interactive online mathematics

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Abstract

Mathematical Markup Language (MathML) and Scalable Vector Graphics (SVG) both have considerable potential for the presentation of mathematical formulae and scientific graphics on the web. They both have the advantage of being XML dialects and their use, together with JavaScript for interactivity, constitutes a powerful synergy. The purpose of this paper is to review the adoption of MathML, SVG, and other XML tools for use in web-based teaching in mathematics and the physical sciences, and to discuss possible future developments.

Introduction

There are several web technologies in existence capable of producing interactive, on-line mathematics. By way of example, two widely used approaches are Flash animation¹ and Java Applets.² In this paper web technologies based on XML (Extensible Markup Language) are discussed. The authors aim is to create interactive, on-line mathematics using JavaScript programming for interactivity using MathML (Mathematical Markup Language) and SVG (Scalable Vector Graphics), and to do it in the context of XHTML, the XML version of HTML. Ideally, a student will be able to interact with every element of a web page, including mathematical expressions and graphics, and be able to see the effect of changing one upon the other.

The objective of this paper is to give a brief introduction to the XML dialects of MathML, SVG and XHTML and to discuss how they may be combined, using JavaScript, to produce interactive, online mathematics for education and research communication. MathML is a dialect of XML, and, like HTML, XML uses tags to markup the data contained within. But whereas HTML tags are fixed and describe the appearance of the data only, XML tags are user-defined and produce structured, self-describing data.

¹Available from: <http://www.edumedia-sciences.com>

²Available from: http://dmoz.org/Science/Math/Education/Java_Applets/

HTML	XML	MathML(C)
<code><html></code> <code><body></code> <code><h3>Hello
World!</h3></code> <code></body></code> <code></html></code>	<code><person></code> <code><name></code> <code><first>John</first></code> <code><last>Doe</last></code> <code></name></person></code>	<code><math><apply></code> <code><power/></code> <code><ci>x</ci></code> <code><cn>2</cn></code> <code></apply></math></code>
Hello World!	Formatting of "John Doe" depends on the stylesheet.	x^2

Figure 1: Comparison of HTML, XML and MathML(C) outputs.

There are two kinds of MathML; presentation and content. The MathML shown in column three of Figure 1, under MathML(C), is content MathML. Content MathML is based on the use of prefix, or Polish, notation which is used widely in computer science for its conciseness. For example, '+23' in prefix notation, is interpreted to mean '2 + 3' in the more widely used notation. To represent the square of x it is denoted as '^x2', or 'expx2' in place of the more usual 'x2'.

Content MathML is used to capture the mathematical meaning of an expression. If the goal is to display a formula only, then presentation MathML can be used instead. For the same expression in presentation MathML see column 1 of Figure 2 under MathML(P). Shown also is the XML version of HTML, called XHTML. The main difference between the two is that XHTML is grammatically strict, whereas HTML is not. For example, HTML allows an opening tag without the corresponding closing tag. In XHTML, an opening tag like <name> must always be accompanied by the closing tag, </name>. This difference can be seen in the change to the 'break' tag,
. It becomes an empty tag
 – short for

 – which is a tag with no content.

MathML(P)	XHTML	SVG
<code><math><mrow></code> <code><msup></code> <code><mi>x</mi></code> <code><mn>2</mn></code> <code></msup></code> <code></mrow></math></code>	<code><html></code> <code><body></code> <code><h3>Hello</code> <code>
</code> <code>World!</h3></code> <code></body></code> <code></html></code>	<code><?xml version="1.0" standalone="no"?></code> <code><!DOCTYPE svg</code> <code>"http://www.w3.org/Graphics/SVG/1.1/DTD/svg</code> <code>11.dtd"></code> <code><svg></code> <code><rect x="400" y="200" width="50" height="50"></code> <code></svg></code>
x^2	Hello World!	A rectangle located at position (400, 200): width 50 pixels, height 50 pixels.

Figure 2: Comparison of MathML(P), XHTML and SVG outputs.

SVG is a language for defining graphics and its purpose is to represent visual appearance. SVG was created by the World Wide Web Consortium (W3C) (W3C, 2006) to handle vector graphics display and animation in XML. SVG is entirely text-based and is easily human readable. It is editable in text editors, but being verbose, like XML, it is not meant to be generated by hand.

The problem with JPEG images and GIF files is that they are raster graphics and use bitmaps. Because of this, when a JPEG image or GIF graphic is enlarged the picture becomes fuzzy. On the other hand, because SVG uses mathematical statements to describe the image, it is resolution independent. Due to this vector nature, SVG files can be quite small in size and are easily transported over the Internet. After downloading and expanding, the image retains the same resolution and quality since the mathematical formulae describing the image do not alter (Eisenberg, 2002).

SVG has the advantage of having an open, compact and portable source code. It is easily editable by individuals having little or no programming experience. Complex images can be created using transformations such as scaling and rotations. Its content is searchable because the graphics are text-based and, being a dialect of XML, SVG offers the advantage of being truly designed for data handling. SVG can exist on its own, or work hand-in-hand with other technologies. It can be used within an XML document, be referenced from HTML, display JPEG images, and can also utilise JavaScript and Cascading Style Sheets (CSS). SVG's capabilities can be extended with CSS; every line, shape and style property can be controlled and customised. With SVG, graphics can be personalised (Pearlman and House, 2003).

MathML

XML 1.0 was recommended by the W3C in 1998 and in the same year the first XML applications, or dialects, began to appear. MathML 1.0 was the first such XML application to be recommended by the W3C. One of the practical objectives of MathML 1.0 was to make it possible to copy and paste expressions from web pages straight into computer algebra systems. Existing mathematical typesetting languages, such as $\text{\LaTeX}$, were not considered capable of capturing the true semantic meaning of mathematics and this led directly to the design philosophy of having separate presentation and content versions of MathML (Wolfram Research, 2006).

The current version, MathML 2.0 (Second Edition), dates from 2003. MathML was redesigned to make it more compatible with key web technologies, such as CSS, eXtensible Stylesheet Language Transformation (XSLT), and the Document Object Model (DOM). The latter is considered essential for interactivity using scripting languages like JavaScript. Work on a new version, MathML 3.0, is now underway with the intention of maintaining MathML and keeping it in line with ongoing work on related web technologies, such as Unicode and SVG. It is also hoped to add new functionality in areas like notation, equation numbering and educational applications. At the moment, the range of symbols covered by MathML is consistent with undergraduate mathematics and there is a desire to extend this as well as to improve the precision of presentation MathML (W3C, 2006).

The use of XML as a language for encoding web-based mathematics confers considerable advantages over conventional typesetting languages. Machine readability leads to greater accessibility, mathematical expressions become searchable, and MathML functions can be copied and pasted into MathML aware software (Rowlett, 2006). XML, including specialised dialects like MathML, is intended to be the bottom layer in a two-layered architecture. The top layer consists of software applications for the user to interact with, free of low-level implementation issues. In future, autonomous

software agents may be added to make possible the semantic web (Carlisle, 2003).

Being an application of XML, the rules for using elements and attributes in MathML is determined by a separate document called a Document Type Definition (DTD) or schema. And the appearance, or formatting, is set by another separate document called a stylesheet which can take the form of either a CSS or an XSLT. Both the presentation and content MathML for the expression 'x + y' are shown in Figure 3. The DTD entries are for illustration only; the actual W3C DTD is considerably more complex (W3C, 2006).

DTDs use Extended Backus-Naur Format (EBNF) and the top entry, under 'DTD', states that one <math> element must contain at least one <mrow> element ('+' means '1 or more'). The second entry states that an <mrow> element may contain zero or more (represented by "**") <mi> or <mo> or <mn> elements, in any order. PCDATA (Parseable Character Data) consists of text or numerals (Sandhu, 2003).

DTD	Presentation MathML	Content MathML
<! ELEMENT math (mrow+)>	<math><mrow>	<math><apply>
<! ELEMENT mrow (mi*mo*mn*)>	<mi>x</mi>	<plus/>
<! ELEMENT mi (#PCDATA)>	<mo>+</mo>	<ci>x</ci>
<! ELEMENT mo (#PCDATA)>	<mi>y</mi>	<ci>y</ci>
	</mrow></math>	</apply></math>
	x + y	x + y

Figure 3: Comparison of DTD, presentation MathML and content MathML outputs.

It is easy to tell at a glance whether one is looking at presentation or content MathML. Presentation MathML has elements that all begin with the letter 'm'. Elements like <mrow> and <apply> are container elements and <plus/> is an empty element. In row two of the presentation MathML column of Figure 3, <mi> is the start tag, 'x' is the content, and </mi> is the end tag of the 'mi' element and is referred to simply as the <mi> element. When creating MathML it is necessary to bear in mind that there are additional restrictions on the values of some attributes and child elements beyond those required by the rules of XML. For example, the <msup> element can only have two child elements, called arguments. The first is always the base, and the second is always the superscript (Sandhu, 2003).

Current uses of MathML include static display in a web page, as a data format for computation, and also for communication over the Internet. MathML is becoming increasingly widespread as more application software becomes available to author it. What are the problems with using it? A certain amount of low-level implementation is still required, or to put it another way, programming skills still help a great deal. Software exists to convert MathML to and from existing mathematical typesetting formats such as TeX and PDF (Sandhu, 2003). Many mathematicians can already author in L^AT_EX and prefer to prepare documents using familiar applications for translation into MathML. The authoring and displaying of MathML and SVG are topics in their own right and we discuss them below.

SVG

SVG is best used for diagrams, such as the graph of a function, and is widely seen as the ideal companion technology to MathML. This is due in no small part to the fact that it possesses sophisticated built-in animation and interactivity capabilities. Animation has long been the aim in web graphics. Bringing static imagery to life with motion can convey a difficult concept. It can evoke a message, a meaning, or even a deep emotional feeling. SVG animation basically involves changing one or more properties of a graphic over time and can involve either starting at a specific moment or responding to a given event, such as a mouse click. The animation can take the form of a change in the position of an object, or a transformation such as rotation or scaling. It can also involve cycling through various colours, or making an object change opacity.

In terms of coding, SVG can be animated in two ways. One way is via a tag declarative approach that uses SVG's own animation elements, which are quite extensive. The second way is by scripting animation using a language like JavaScript. Animations that require scripting are usually interactive, more complex, and harder to program. SVG animation basically involves changing one or more properties of an object over time. The object can move, rotate, change colour, size, visibility, opacity, or any number of the above visual changes at the same time. The object starts at a specified time and ends at a specified time. For SVG animation, there are five declarative elements: `<animate>`, `<set>`, `<animateColor>`, `<animateMotion>`, and `<animateTransform>` (Pearlman and House, 2003).

The `<animate>` element can be used to create different types of animations and is the most basic and versatile animation element in SVG. The `<set>` element sets the value of an element for a specified period of time. The `<set>` element does not change the value incrementally over time like the `<animate>` element, it changes the value instantly. The `<set>` element has an 'on/off' quality. The `<animateColor>` element is specific to colour and changes the colour of an object over time. The `<animate>` element is not colour specific.

The `<animateMotion>` element moves objects along a designated path. The `<animate>` element can control linear motion but with `<animateMotion>` the object can be animated along curved paths, cornered paths, and winding paths. The `<animateMotion>` can also do linear motion, but the `<animate>` element does this so well that a programmer is better off using `<animateMotion>` only for more complex paths.

The `<animateTransform>` element animates transformations, including translation, rotation, changing scale, `skewX`, and `skewY`. To use it, one must specify at least one of the transformations that are to be performed. The use of the `<animateTransform>` element allows movement other than just simple translation. For example, objects can be made to spin around, grow larger or smaller and distort. The `<animateTransform>` element can significantly expand a programmer's repertoire of animation techniques (Laaker, 2002).

SVG also has the ability to work with JavaScript,³ or its open standards version, ECMAScript. JavaScript is a language originally created by Netscape and is the most commonly used language amongst web developers. A script, in this context, is a program written in some (relatively) simple language that carries out a task within a doc-

³Available from: <http://www.javascript.com>

ument, such as an SVG document or a web page. To add a script to an SVG file one uses the `<script>` element. For instance, if a programmer were inserting JavaScript, the following code would be added to the SVG document: `<script type="text/javascript">...</script>`. The dots between the script tags show where the script code would be placed. For ECMAScript, the coding would be the same as above except 'javascript' would be changed to 'ecmascript': `<script type="text/ecmascript">...</script>`. Alternatively, a programmer can choose to link an SVG document to an external script file by using the 'xlink:href' attribute. In the following code, 'externalFile.js' represents the name of the script file: `<script type="text/javascript" xlink:href="externalFile.js"/>`.

Authoring and displaying MathML

Mathematical documents on the web, written using MathML, are no longer rare. But once written, MathML is, unfortunately, not readily displayable across all browsers in a uniform fashion. As a general rule, MathML on a web page appears in '`<math>math content </math>`' islands inside the HTML or XHTML. How, or whether, it is displayed in a particular browser depends first on whether HTML or XHTML is being used, and also on other factors such as the MIME type of the document (text/html for Internet Explorer and text/xml for FireFox), the particular DOCTYPE declaration in the top matter, the use of namespaces, and on any extra tags that may need to be inserted.

In this discussion, focus is on MathML prepared for display in Amaya (W3C, 2006), the W3C test browser, FireFox,⁴ the open-source successor to Netscape, and, finally, Microsoft's Internet Explorer (currently IE 7); all running under the Windows operating system. Both Amaya and FireFox have built-in MathML rendering, but Internet Explorer requires a plugin, such as Design Science's MathPlayer⁵ or IBM's techexplorer.⁶ There are also other technical factors to consider. For example, can the browser apply XSLT stylesheets? If so, must the stylesheets be located on the hard disk, or can they be remote? Another important issue is the special fonts needed for mathematical characters.

Only Amaya is capable of displaying 'pure' MathML, such as that shown in Figure 1. The absence of a requirement to use namespaces means that the presentation MathML markup can be mixed with HTML tags. Amaya can also be used to author and edit presentation MathML and has the useful feature of being able to display the MathML input and the mathematics output on split screens. Amaya files can be either HTML or XHTML but Amaya cannot render content MathML or apply XSLT stylesheets.

Mozilla also has an inbuilt ability to render presentation MathML, but it must be part of an XHTML file. An XHTML + MathML file prepared for display in Mozilla FireFox will have the standard XML declaration, `<?xml version="1.0"?>`, as well as an appropriate DOCTYPE declaration. FireFox files are XML files ensuring that the MIME type is text/xml. To display MathML in the FireFox browser it is necessary to have already installed the appropriate fonts required for mathematical symbols. The Computer Modern fonts, which are part of L^AT_EX, can be obtained from the American

⁴Available from: <http://www.mozilla.com>

⁵Available from: <http://www.dessci.com/en/products/mathplayer>

⁶Available from: <http://www.integretechpub.com/techexplorer>

Mathematical Society (AMS).⁷

Internet Explorer has no native MathML display capability and requires plugins such as Design Science's MathPlayer or IBM's techexplorer. MathPlayer is free and is the easiest to download and install. It is actually an IE behaviour; that is, it can query the browser about the document formatting and use it to render the equation in a similar style. An HTML + MathML document authored for MathPlayer uses a namespace to indicate the MathML; `<m:mrow>` would be needed instead of just `<mrow>`, for example. Also required are two additional tags: `<object>` and `<import>`. Some simple interactivity is built in to MathPlayer. For example, when an equation displayed in a web page is clicked, it is shown in a highlighted form.

The other plugin for Internet Explorer, techexplorer originally from IBM, is now supplied by the Integre Publishing Company. It has the advantage of allowing interactivity through scripting with JavaScript or Java. A HTML + MathML document authored for techexplorer does not require a prefixed math namespace, but does require one additional tag, the `<object>` tag. Techexplorer renders both presentation and content MathML in a wider variety of browsers than MathPlayer. Techexplorer can also be used as an IE Behaviour and both MathPlayer and techexplorer can be plugged in to FireFox with similar document design requirements.

For the newer browsers, the ones that can use stylesheets, a solution devised by David Carlisle of the W3C to ensure that MathML will always display, is to use the 'Universal MathML Stylesheet' (W3C, 2006). This stylesheet conditionally transforms a document into the correct format for display in whatever browser is being used by the client. For example, if the document contains content MathML it is first converted into presentation MathML. After that, any additional markup that is needed is added by the stylesheet. The stylesheet can even make a decision as to whether to use the native rendering of a browser, if any, or to select from a list of add-ons, according to the preference of the author. Finally, if no other rendering is available, the stylesheet can use a combination of CSS and JavaScript to default display the MathML.

MathML is not designed to be typed by hand as it is too verbose. There are various approaches to MathML document preparation depending on the quality and quantity of the MathML output required. Amaya, which is free, can be used to author relatively unsophisticated presentation MathML. Its relative simplicity recommends it as a good introduction to MathML and SVG. At the same level is EZMath which is a simple authoring tool for content MathML. EZMath uses an intermediate markup language based on mathematics spoken in English. For example, an integral could be represented as 'the integral from a to b of x squared with respect to x ' and saved as content MathML.

At the other end of the spectrum are the professional level, and consequently, expensive authoring tools like Scientific Word, Mathematica, Publican, Maple, etc. A leading example is Mathematica which can perform all the tasks that a MathML authoring tool should ideally be able to do. It can create both presentation and content MathML and customise the output, set namespaces, markup, etc., for a particular display browser. An author can create individual formulae as well as complete documents.

In between these two extremes is a cost-effective option that would satisfy many authors. This involves the use of MS Word in conjunction with the professional level

⁷Available from: <http://www.ams.org>

version of the equation editor, MathType from Design Science. MathType uses a palette interface to create and insert equations and allows the user to save the document as a web page using a technology called MathPage. The MathML + HTML file generated can be marked up for viewing by a particular browser and plugin.

Authoring and displaying SVG

Currently, neither Internet Explorer nor FireFox has native browser support for SVG. Fortunately, there are numerous plugins that are available. By far the most popular of these is the one from Adobe Systems called the SVG Viewer, currently nearing the end of its product life.⁸ It can be used by both Windows and Macintosh and, in terms of functionality, it is considered to be the best overall implementation of the SVG specification, especially for Macintosh computers.

Another free SVG viewer is the SVG browser Squiggle which is part of the Batik toolkit. Batik is a Java-based technology toolkit for programs that use images in SVG format. It is an open-source project developed by the Apache Software Foundation. The operating system is any Java platform and Batik is fully SVG loaded.⁹

Another SVG plugin viewer is included in the web browser Opera.¹⁰ Operating systems that can run Opera include Windows, Macintosh, Linux, Solaris and Free BSD. Opera supports SVG 1.1 'Basic', and parts of SVG 1.1. 'Full' public releases are available and weekly builds can be downloaded from the blog of the desktop-team.¹¹

With so many different SVG rendering systems, SVG documents may not work in all of them. For example, documents that display with Adobe's SVG Viewer may not work with Mozilla and Batik. This failure is not really an issue with SVG itself; server mal-configuration is a very common reason for an SVG document not loading. Some browsers, for security reasons, handle files by first looking at the HTTP headers sent by the servers. If the server is configured wrongly, and did not send the correct headers with the SVG files, then a browser like Mozilla will not recognise the file as SVG.

SVG is an XML dialect, and like all XML dialects, it must be bound to its namespace. At a minimum, it is good practice to bind the SVG and XLink (XML Link language: hyperlink for XML) namespaces. Also, it is a good idea to bind the XML events namespace. Even if XLink or XML Events are not used immediately in an SVG document, the inclusion of the bindings will prevent annoying errors if it is decided to use them later (Jwatt, 2006).

A relatively new shareware product that is available for evaluation is SVGDeveloper.¹² SVGDeveloper 1.0 is a powerful software program to develop SVG applications and making use of the design capability of the software, users can 'draw' most shapes, texts, images, and so on. Using the powerful source editor of the software, users can write any complex SVG application. Its features include transforms, support for animation, CSS support, namespace handling, good colour handling, built-in intelligence, etc.

⁸ Available from: <http://www.adobe.com/SVG>

⁹ Available from: <http://xml.apache.org/batik>

¹⁰ Available from: <http://www.opera.com>

¹¹ Available from: <http://my.opera.com/desktopteam>

¹² Available from: <http://www.svgi.org>

There are new SVG applications being created every year. One promising SVG program, which is available in beta format, is called Extensible SVG Optimiser.¹³ This is a freeware product that is available for most operating systems, such as Linux, Solaris, Windows and Macintosh.

MathML and SVG in use on web pages

Examples of the effective use of MathML and SVG in web pages, either separately or in conjunction with each other, do exist. The problems that occur with using MathML and SVG in synergy constitute a subset of the more general problem of making XML dialects work together on the same web page. The technical issues that must be confronted are concerned mainly with the use of XML namespaces and the differing behaviours of the various web browsers with respect to XML. Listed below are some current examples of the use of MathML and/or SVG available on the web.

Animated Math¹⁴ illustrates some of the ideas of mathematics in dynamic form, including cycloids, derivatives and coordinate transformations. It does so by using the built-in animation features of SVG, meaning that the animations run on their own without the need for scripting. SVG animations like this are relatively easy to write, but have the downside that there is no user interactivity. The Animated Math web page is written using XHTML, that is, it is an XML document using the XHTML namespace. The SVG animation sequences are initiated when the user clicks on a hyperlink to a separate SVG document and the SVG runs in a new window. A right-click brings up a context menu allowing the SVG animation to be saved to the hard disk and run in a web browser independently of the original web page. SVG animation used in this manner is a promising alternative to Java applets, SVG code being much easier to write than the Java programming language.

Reflection (Dobbs, 2003) gives an example of a simple, interactive SVG animation embedded in an HTML web page. Embedding here means that the graphic is visible on load and does not require a hyperlink. Scripting with ECMAScript allows the user to start and stop the animation which is an illustration of the vanishing point of perspective. The SVG animation is also stored in a separate document which can be downloaded and run separately in a web browser.

An MIT online book for a calculus course, *Calculus with Applications – 18.013A*¹⁵ is a good example of the use of static MathML in an XHTML web page. The presentation MathML islands carry the namespace prefix ‘m’, <m:mathml> for example. The graphs of the functions are not done with SVG but rather use the JPEG picture format.

In order to go beyond static MathML it is necessary to use a scripting language. For example, in instructional mathematics there is a need to give the student the option of seeing all the steps in a mathematical development. With scripting this can be done at the click of a button. But to go beyond conventional web pages, that is web pages that can only be read from and not written to, it is necessary to make use of other web technologies like the Wiki web page concept. Wiki web pages, which are also based on the use of a scripting language such as JavaScript or ECMAScript allow a much

¹³Available from: <http://myfriendsnet.com/svg>

¹⁴Available from: <http://mathanimated.com>

¹⁵Available from: <http://www-math.mit.edu/18.013A/MathML/chapter01/section04.xhtml>

greater degree of interactivity. One application, described below, allows the user to actually write MathML to a web page.

Jipsen (2006) has developed an approach to web-based mathematics which, in the opinion of the authors, is the best that has been demonstrated so far. It is a synthesis of the Wiki web page concept, web pages the user can write to, together with two JavaScript programs called ASCIIMathML and ASCIIsvg. The ASCIIMathML translator allows the user to type MathML into a web page via the intermediary of formulae typed in an ASCII format. For example, x^2 would be typed `x^2`, and $x_{(n+1)}$ would be typed `x_(n+1)`; the ASCIIMathML translates the ASCII into MathML in real-time and the user sees the mathematics displayed immediately. An introductory tutorial to ASCIIMathML has been written by Gray (2006). ASCIIsvg is a set of JavaScript functions that can create a conventional X–Y axis and draw the graph of a function.

Mixing XHTML, MathML and SVG in the same document requires a mechanism for validating the mixed-namespace document. Validation means checking the structure for conformity to the DTD or schema. A proposal for an XHTML+MathML+SVG profile, created by Masayasu Ishikawa is described on the W3C web site (W3C, 2006). It consists of a combined DTD for all three dialects and is primarily aimed at XHTML documents which contain MathML and SVG fragments. The DTD driver allows for the use of the Universal MathML stylesheet for rendering. Creating a web page that allows a full range of user interaction, via JavaScript say, between XHTML, MathML and SVG will require the use of such an environment.

Discussion

The problem of creating XML documents that combine several different XML dialects is being addressed by the W3C. A Compound Document Format (CDF), which is a proposed W3C standard to specify the behaviour of multiple formats, is being developed. Such a standard will be needed for the web to become fully interoperable.

The slow adoption of XHTML is a problem. The widespread use of XHTML would assist the adoption of other XML dialects, like MathML. One solution that has been proposed is to incorporate MathML directly into HTML. XML is the base layer of the proposed Semantic Web and another related XML development for mathematics is OpenMath. But OpenMath focuses entirely on the semantics or meaning of mathematical expressions and MathML is, by now, well established as the standard for web-based mathematics communication.

The new web technology Asynchronous JavaScript and XML (AJAX) looks very promising for use with interactive mathematics web sites. AJAX gives web page response times similar to those of desktop applications. By managing the timely download of data and programming code, a user does not have to wait long periods for a server response.

In conclusion, the synergistic use of XHTML, MathML and SVG is rapidly becoming a mature web technology and many open-source programs now exist for mathematics communicators to use the web in ways that were not possible just a few years ago. A particularly effective example is the innovatory approach of Jipsen (2006) with the programs ASCIIMathML, ASCIIsvg and ASsciencePad.

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Science

Using the force concept inventory for engineering physics in the United Arab Emirates

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Abstract

The Force Concept Inventory is a widely used tool for assessing student understanding of basic Newtonian mechanics concepts. Its use internationally, over a decade or so, has provided a considerable body of comparative data and established a high degree of validity. The work reported here uses both English and Arabic versions. A longitudinal study has been undertaken with one group of engineering students taking the first-year introductory physics course at The Petroleum Institute. 'Pre' and 'post' course outcomes are assessed for possible indicators that may serve to improve course delivery and student learning. A second study, involving students taking a second-year physics course, was designed and undertaken to address the 'second language' issue in survey implementation. The authors discuss their findings in light of an earlier study carried out at the Institute in 2002, and with respect to international findings and trends.

Introduction

This study evolved from the continuing effort to improve teaching and learning effectiveness on the introductory physics course PHYS191 at The Petroleum Institute (PI), Abu Dhabi. PHYS191 is a standard, one semester, mechanics based first-year course. The idea was to gain more systematic evidence about students' knowledge and understanding using well-tested, research-based instruments and to track subsequent progress. Attempts to improve introductory physics courses using systematic pre- and post-course testing have a history dating back thirty years or more. Possibly the most carefully researched and widely used test for this purpose is the Force Concept Inventory (FCI), initially developed by David Hestenes and his collaborators at Arizona State University (Hestenes, Wells and Swackhamer, 1992). A revised version (Halloun, Hake and Mosca, 1995) claims to improve clarity and question sequencing, and provides a thirty-item, multiple-choice instrument, designed according to its authors, 'to assess student understanding of the most basic concepts in Newtonian mechanics'.

Numerous studies have been undertaken using the FCI and Richard Hake (Hake, 1998) has compiled a database of pre- and post-test results involving over 6000 students from across the US. In his evaluation Hake (1998) addresses issues of validity

and reliability of the FCI and notes that even its detractors concede the FCI is ‘the best test currently available ... to evaluate the effectiveness of instruction in introductory physics courses’ (Heller and Huffman, 1995). After a decade, it remains the most commonly used test and, indeed, its position has been strengthened by the large amount of comparative data now available to benchmark new studies.

The work reported here seeks to benefit from this feature and, in particular, to provide direct comparisons with an initial study carried out at the PI in 2002 (Mealy, Al Hashemi, Olds and Miller, 2002).

Study design

The full revised 1995 version of the FCI was used in both English and Arabic translation. The Arabic translation was based on that used in the previously cited PI study with the addition of seven questions from the complete English version which were originally omitted from the Arabic translation at that time.

The present work has two strands. The first of these attempted to examine the teaching and learning effectiveness of the PI introductory physics course PHYS191. The autumn 2006 entry cohort was given the English version of the FCI as pre- and post-test. These students had each completed one year of introductory science at the PI as part of their Foundation year programme. Of these students, 57 completed both pre- and post-tests and only their data were used for calculating averages and gains.

The second strand focused on a student group who had successfully completed PHYS191 and were now the autumn 2006 entry for the second stage of PI introductory physics – PHYS241 (Electricity and Magnetism). The intention here was to provide comparisons with previous findings and to look again at the language issue of testing students who are learning in a second language. For this group of 64 students, 31 students were given the English version of the FCI while 33 were given the Arabic version.

Results

In order to reflect Hake’s original presentation (Hake, 1998), Figure 1 shows the individual student gain against pre-test score for each student in the PHYS191 student group. The different symbols (●, □, △) indicate students linked with a particular section lecturer. Three data points overlap (two at pre-test score 20%, one at pre-test score 30%). These have been shifted slightly (2%) in order to be displayed.

The lines (A, B, C, D) indicate specific values of normalised student gain G . This is defined as the change in score divided by the maximum possible increase:

$$G = \frac{\text{post-test score\%} - \text{pre-test score\%}}{100 - \text{pre-test score\%}}$$

The gradient of line A corresponds to a normalised gain of 100%, line B – 70%, line C – 40%, and line D – 10%.

The data points in Hake’s presentation (Hake, 1998) represent average scores for large numbers of sample groups. While the data points in Figure 1 represent individual

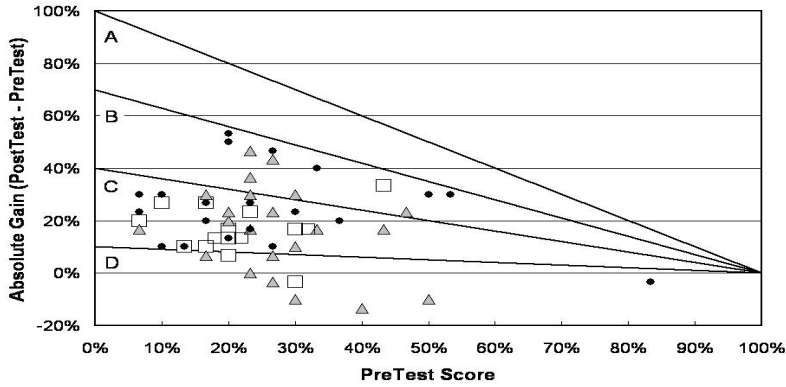


Figure 1: Scatter plot of individual student gain against pre-test score on the FCI for PHYS191 student group.

students, it shares the property of having no data points above the 70% line (B). It also shows the large degree of variance within the sample.

In compliance with Hake's advice (Hake, 2001), the results have been analysed where appropriate to give:

- (i) the pre-test group average $\langle \%pre \rangle$ with its standard deviation,
- (ii) the post-test group average $\langle \%post \rangle$ with its standard deviation,
- (iii) the group average normalised gain $\langle G \rangle$ where

$$\langle G \rangle = \frac{\langle \%post \rangle - \langle \%pre \rangle}{100 - \langle \%pre \rangle},$$

- (iv) the average of the single student gains where

$$G_{av} = \frac{1}{N} \sum_i g_i = \frac{1}{N} \sum_i \frac{post_i - pre_i}{100\% - pre_i},$$

- (v) the correlation of individual student gain G and pre-test score.

Data from previous studies vary as to whether $\langle G \rangle$ or G_{av} is given as a basis for comparison. Hake has argued (Hake, 2001) that $\langle G \rangle$ may be a better indicator of teaching effectiveness as it lowers the contribution to the average of students who score highly in the pre-test, when their resulting gain is limited. In practice the values are often found to be reasonably close.

No correlation was found between individual student normalised gain $\langle G \rangle$ and pre-test score $\langle \%pre \rangle$ and at this stage the low sample number precludes sensible discussion about statistical significance.

Pre-test $\langle \%pre \rangle$	Post-test $\langle \%post \rangle$	Absolute gain $\langle \%post \rangle - \langle \%pre \rangle$	Normalised gain $\langle G \rangle$	$G_{av} \%$
25.5 ± 13.5	45.0 ± 17.9	19.5 ± 14.7	26.2 ± 20.0	25.9 ± 21.8

Table 1: PHYS191 group data averages.

	FCI Score % average	Average class exam grade %
FCI English	50.8 ± 21.6	75.8 ± 15.7
FCI Arabic	42.6 ± 12.5	55.7 ± 14.1

Table 2: Average percentage FCI score and average percentage class examination grade for the PHYS241 group.

Correlations between class examination grade and FCI score were higher (0.50) for the FCI English group than the FCI Arabic group (0.10) but again the low sample numbers involved preclude any discussion about statistical significance at this stage. The data may also be presented in quartile format, i.e. number of students scoring less than 25%, numbers scoring 25% or more but less than 50%, etc.

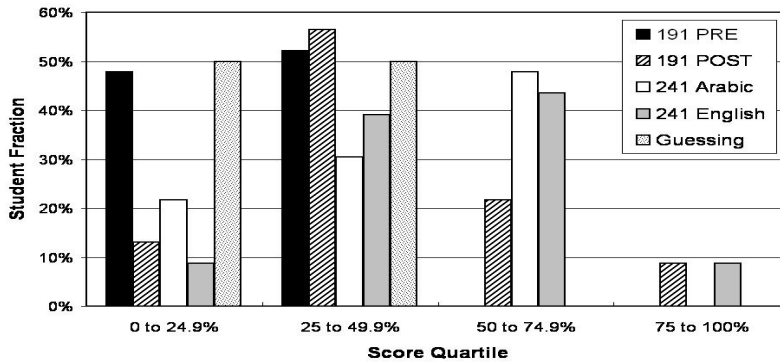


Figure 2: Quartile data for the various student groups studied.

The final column in each set gives the predicted values for students randomly guessing their FCI responses (nearly 50% each for the lower two quartiles, near zero for the others). It has been argued (Halloun and Hestenes, 1985) that the presence of effective distractors in the FCI responses may lead to non-Newtonian thinkers scoring below the random guessing level.

Comparisons and discussion

The results allow internal comparisons within the specific groups tested – pre/post and Arabic/English, comparisons with the previous study at the PI (Mealy, Al Hashemi, Olds and Miller, 2002), and comparisons with international findings. For international comparisons it is important to note the programme structure and language implications at the PI. Students normally enter from secondary school where the teaching is usually in Arabic. At the PI, they first take a Foundation year which uses essentially secondary school material and focuses on language and communication issues, followed by first, second, third and fourth years. Teaching at the PI is in English.

Internally, Table 1 shows an acceptable normalised gain for students taking PHYS191 suggesting a degree of effective teaching. In addition Figure 2 suggests that the gain is achieved through a general population ‘shift’ with fewer students below 25% post-test and approximately the same increase of students scoring above 50%. Hake (Hake; 1998) generalised two types of teaching style – interactive engagement (IE) methods and ‘traditional’ methods. In his survey he finds ‘traditional’ methods produce, on average, a gain of 23% while IE methods gave, on average, 48%. Lecturers teaching PHYS191 would claim a reasonable degree of IE for their approaches. While the gain achieved (26%) exceeds the ‘traditional’ average there may be other factors involved here which reduce the expected effect.

Mealy’s 2002 study did not establish gains within groups but reports average scores for different groups. He reported significant differences in the average scores of freshman students taking an Arabic version of the FCI with those taking an English version. The Arabic group achieved a higher average score and a higher percentage scored 25% and above. Mealy and co-workers claim that the Arabic group average scores are comparable to those of students at a similar stage of their education in the US, although there are fewer individual scores above 50%.

By contrast, the present study found higher scores with students taking the English version FCI (see Table 2). These groups had spent six to twelve months longer at the PI compared to those in Mealy’s study and the finding might suggest a decrease in the language effect due to increased exposure to English instruction. However while the administration of the English–Arabic FCI tests was designed to be random a subsequent analysis of student class performance showed the English group to have had higher PHYS191 grades on completing that course. This obviously complicates the issue.

Table 1 gives the average pre-test score as 25.5% for students taking the test in English. This seems significantly lower than Mealy’s figure of 35.4% for students at the same stage of their PI programme. Mealy’s students took the test in Arabic (the figure for Mealy’s English group is not given). Alternative possible explanations are that perhaps the PI average entry quality is lower at this time or again that the language issue is an important factor at this stage. Further work is needed if this is to be resolved.

An interesting internal comparison is between the post-test FCI performance of the PHYS191 group and the PHYS241 group (see Figure 2). Although having spent about six months more at the PI, the PHYS241 group have received no further specific instruction on the concepts covered in the FCI. Nevertheless, the quartile distributions show a marked increase in the number of students scoring 50% or more. It must be kept in mind that these are different student populations, but again this could be due to a decrease in the language effect after increased exposure to learning in English.

No overall correlation was found between individual student gain G and pre-test instruction score for the PHYS191 group (Table 1, raw data). This corresponds to Hake's general finding over a very much larger study and, in theory, allows the observed gain to be attributed more fully to the instruction. However, Coletta and Phillips (2005) have recently established that, even where no overall correlation exists, correlations may still exist between subsets of the population under study and that 'hidden variables' may have significant effect in individual cases. Some evidence of this was found in the current data, although, as yet, the small numbers involved preclude presentation or any definitive statement.

Conclusions and further work

The analysis presented here must be considered preliminary but some tentative statements may be made. As other workers have found, the FCI provides a readily accessible, objective measure of learning in introductory mechanics. The average normalised gain (G) is a useful indicator of teaching effectiveness. Mechanics instruction at first-year level at the PI currently produces gains deemed acceptable in the international community. However, questions remain unresolved regarding the influence of culture and language when using standard instruments in new contexts. Further work is required and, indeed, is ongoing at the PI in an attempt to resolve these issues. This effort would be greatly enhanced if similar data can be collected and reported from other institutions in the region.

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Just-in-Time Teaching method for a physics course with BlackBoard used as the interaction tool with students

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Abstract

Just-in-Time Teaching is a learning strategy based on interaction between student and teacher through web-based assignments to encourage students to prepare and assess their level of understanding of different concepts of the coming lecture. On the one hand, Just-in-Time Teaching aims to maximise the efficacy of the classroom session when the teacher is present, so that the lecture is specifically tuned to address the needs of the present audience and, on the other hand, to structure students' out-of-class time for maximum learning benefit. This creates and sustains a team spirit between teacher and students, facilitating the learning process. Carefully designed questions for each lecture are assigned to students in a general physics course before class through BlackBoard. Student response helps tailor the lecture accordingly and guide how to spend time efficiently on the items that students do not grasp well. This before-class feedback will allow for the preparation of a variety of ways to present a specific physical concept to students with different capabilities and to spend the extra time on new materials and problem solving.

Introduction

Given today's culture and availability of different technological tools, students can no longer be left on the receiving end in the classroom. Active learning methods have proven beyond doubt that the participation of the student in the learning not only makes learning a fun and challenging activity, it substantially improves the quality of learning as well (Johnson, Johnson and Smith, 1991; Bonwell and Eison, 1991; McKeachie, 1994; Prince, 2004).

Active learning is defined as 'students being engaged in more activities than just listening. They are involved in dialogue, debate, writing, and problem solving, as well as higher-order thinking, e.g., analysis, synthesis, evaluation' (Bonwell and Eison, 1991). On the other hand, collaborative teaching is defined as 'the instructional use of small groups so that students work together to maximise their own and each other's learning' (Johnson, Johnson and Smith, 1991).

A recent study by Prince (2004) examined evidence for the effectiveness of active learning. It defines the common forms of active learning most relevant for engineering and critically examines each method. It is found that there is broad but even support for the core elements of active, collaborative, cooperative and problem-based learning.

Just-in-Time Teaching, a collaborative teaching method, has been used in teaching a number of different courses and has proven to be effective in customising the teaching of audience-designed materials which substantially increases the level of understanding of course material (Handelsman, Ebert-May, Beichner, Bruns, Chang, DeHaan, Gentile, Lauffer, Stewart, Tilghman and Wood, 2004).

Just-in-Time Teaching method

Just-in-Time Teaching (JiTT) is a learning strategy based on the interaction between student and teacher through web-based assignments to encourage students to prepare and to assess their level of understanding of the different concepts of the next lecture. On the one hand, JiTT aims to maximise the efficacy of the classroom session, when the teacher is present, so that the lecture is tuned specifically to address the needs of a specific audience, and, on the other hand, structure students' out-of-class time for maximum learning benefit. This creates and sustains a team spirit between the teacher and the student, facilitating the learning process.

The JiTT feedback loop

In a typical JiTT course, the teacher and students interact intensively through the Internet outside the classroom. This is meant to be a long-distance course or any other form of computer-aided course. In fact the teacher plays a pivotal role in JiTT. Before getting into the teaching of new material, the teacher posts different types of course items. These items could be in the form of:

1. Short essays on practical aspects of the course subject matter, with interesting hyperlinks on the web. These will motivate the students to look forward to the lecture because of the relevance of the subject to applications of everyday life.
2. Stand alone instructional material, such as simulation programs.
3. Spreadsheet exercises and short tests about the important concepts to be taught in the very next lecture.

These different types of materials are considered as warm-ups for the next lecture. The reading materials and online-experiments are carefully selected to optimise the preparedness of the students and short tests should be designed in such a way to precisely probe the level of understanding of the different physical concepts.

In this mode of teaching comprised of web-based study assignments and an active learner classroom, students respond electronically to these carefully constructed web-based assignments which are due shortly before class, and the teacher reads the student submissions 'just-in-time' to adjust the classroom lesson to suit the students' needs. Thus, the heart of JiTT is a 'feedback loop' formed by the students' outside-of-class preparation that fundamentally affects what happens during the subsequent in-class time together.

Use of BlackBoard as a tool of web-based interaction

Carefully designed questions for each lecture are assigned to students in a general physics course before class through BlackBoard. The response of the students will help tailor the lecture accordingly and guide how to spend time efficiently on the items that students did not grasp well. This before-class feedback allows for the preparation of a variety of approaches to present a specific physical concept to students and to spend the extra time on new materials and problem solving.

The useful features of BlackBoard, such as the private posting of lecture material, the online-chatting with students, the online assignments, especially the online quizzes and automatic grading of these quizzes, allow for a perfect environment of web-based interaction between teacher and students.

The instant grading and statistics provided by BlackBoard for each online quiz allows the teacher to make an informed guess about how the students feel about the material and how they have understood it. On the one hand, this will allow for catering well-suited lectures for the specific audience of the course while, on the other hand, the students are totally engaged in the making of lecture material in a consistent way, besides the fact that they are actively involved in the learning process of the course material. We believe that BlackBoard provides a perfect technology environment for JiTT requirements for web-based interaction.

JiTT and peer instruction method

One of the deficiencies of the Peer Instruction Method (Mazur, 1997; Benkraouda, 2006; Fagen, Yang, Crough and Mazur, 2000), which involves students in their own learning during the lecture and focuses their attention on underlying concepts through peer interaction, is to have students involved in preparation of the lecture material before class. It turns out that the number of students who do the assigned readings is relatively low, often as low as 30 per cent. This in turn restricts the level of discussion during class time. When combined with JiTT, this problem is largely overcome by assigning students online quizzes prior to each class. The assignments are automatically graded by BlackBoard, WebCT or Moodle and could be included in the overall class assessment of the course. This has increased the number of students doing the readings to about 75 per cent (Novak, Patterson, Gavrin and Christian, 1999). There could be some ungraded reading assignments with questions on parts that the students do not understand well or need more clarification. Prior to each class in the JiTT scheme, the teacher evaluates the students' answers and addresses the parts that need to be further explained and difficulties to be clarified. Usually, the students appreciate the responsiveness of the teacher to their concerns (Novak, Patterson, Gavrin and Christian, 1999).

Conclusion

JiTT could be very useful in getting the students involved in the learning process. Not only are they required to read and prepare prior to coming to class, students make good use of their time and optimise their learning process. Based on the students preparedness, the teacher tailors the lecture to fit the audience and address very precisely the

concerns and difficulties shown in the students' answers. Furthermore, if this method is combined with the peer instruction method, which has proven to be very useful in teaching the basic concepts of different courses through different disciplines, this could lead to substantial improvement in teaching and a much better participation of the students in class discussions.

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Teaching introductory astronomy to non-science majors

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Abstract

An introductory astronomy course designed for non-science majors can do two things well. It can teach students about their place in the universe, and it can show students how science works. It is not meant to train students to be astronomer, but to enrich their lives. This is why it is important to define what an introductory astronomy course designed for non-science majors should do, i.e., defining its goals. Some of the old traditional goals just do not work, such as using astronomy to teach mathematics or physics. The goals must be purely astronomical: (i) to let the students know about their place in the evolution of the universe, and (ii) to let the students build their scientific arguments.

Introduction

The success of an introductory course in astronomy lies in the fact that astronomy is a science of wonder and beauty. There are many questions to ask about the Universe; for example, how did life start on Earth, how did the Solar System form, why is the Solar System structured the way it is, what is a star, what is a galaxy, what are the boundaries of our Universe, and so many other questions. They capture the interest of any human being and it is important to design a course that fulfils student needs. This is not an easy task. What should we teach? An astronomy course can be regarded as the finest introductory science for non-science and science students alike. It touches on what we need to know about ourselves and about science. Astronomy's message is universal. It reaches everyone of us and, as human beings, we want to understand life as we see it on a planet called Earth. Thus, any astronomy course should focus on what will be of most benefit to our students, what will enrich their knowledge, and what will enrich their understanding of the scientific process of learning. Several authors have stressed the fact that an astronomy course is a challenging course (Duncan, 1998) and that many misconceptions rooted in student general knowledge can be quite difficult to overcome.

Astronomy goals

As noted by Seeds (1998), a successful astronomy course must convey the following goals: (i) teach students about their place in the Universe, and (ii) show students how

science works. Two goals may seem too little, but if they are well designed and well implemented they will serve our students well and will create the finest introductory science course within our universities.

The first goal, our place in the Universe, can be taught and approached from both a geometrical and evolutionary point of view. The geometrical point of view is that there is a scale. From the nano-scale to the super giga-scale of the Universe, we may go over a large range of scales in terms of size. This raises the question of where are we? The size, shape, and motion of the Earth, the motion of the sky and the motion of the Sun and Moon are all difficult concepts to grasp quickly since they all involve three-dimensional visualisation. Many students have dealt with these concepts at either primary or secondary school, and they may have found them boring, especially if they are used to memorising facts instead of understanding them. If we focus not on the geometrical point of view, but on the effects these concepts have on our daily lives, we will attract the interests of our students. We can ask our students about the nearest star to the Sun and the time it will take to reach it using our present day technology. They will be quite surprised and find the answer enjoyable if you let them know that it may require 10 000 times the average lifetime of a human being. This lesson is quite important in terms of appreciating our planet Earth and who we are. This is just one example of helping students feel their place in the universe and letting them know that astronomy is not science fiction. Other important examples could be the Earth's seasons and climate and how life on Earth depends on energy from the Sun, the nature of our atmosphere and its relation to global warming, the greenhouse effect, and the hole in the ozone layer. Some issues are controversial and critical. The more they are, the more students will think critically about them.

The second point of view of our first goal, the evolutionary one, can be quite a challenge. We human beings are made of the stuff of stars. What makes us has been processed throughout the history of our universe that may span billions of years in star births and star deaths. The Big Bang, galaxy formation, star formation, stellar evolution, nucleosynthesis, the interstellar medium, planet formation, the structure of planets, and the evolution of planetary surfaces are all part of the story of our atoms.

Our second goal, how science works, is important in terms of teaching students how to evaluate scientific arguments from evidence. Some students may think that gathering evidence is just like gathering facts. They are not used to using evidence to support conclusions or to test hypotheses. We need to show our students how scientists depend on the combined use of evidence and hypothesis to improve our knowledge of our physical world. For an astronomy course, we need to point out the differences between observational, experimental, and statistical evidence. The complexities of scientific thinking go far beyond the traditional scientific method and can fill our course with new insights to help students understand themselves, their society, and their world.

Critical thinking is one thing that astronomy can do better than any other science course. One of the most challenging aspects of teaching an introductory astronomy course is that many students, expecting to be spoon-fed the facts, fail to think critically and begin to lose interest. Students are often numbed by the blizzard of laws, rules, and facts. Astronomy deals with so many unresolved issues, for example, the formation of galaxies, the fate of the universe, and the fate of our own star, where each requires deep critical thought. Quantitative thinking, for example mathematical, is part of any

astronomy course. This shows the students how mathematical thinking can be used in the analysis of observations and the modelling of systems. But too much mathematics is just as bad as too little is. We are not teaching mathematics, but we can illustrate to our students the importance of mathematical thinking in science and other related fields.

Peer instruction in astronomy

By encouraging student participation and interaction during the lecture, peer instruction encourages students to think critically through the arguments being developed, and discuss their ideas and insights with their fellow students (Green, 1998; Zeilik, 2006). Despite the fact that astronomy classes can be large (100–150 students), we can break the students into smaller groups. After presenting a short introduction to the subject being covered, we give all groups a multiple-choice concept question. After a minute or two, the students record an answer and are then asked to turn to other groups to try to convince them of their answers. This will lead to animated discussions. After another minute, the students are asked to reconsider their answers and record them again. A quick poll is taken so we can decide whether to move to another concept, or continue with the same one. As class time allows, this process may be repeated several times using different concept questions. But for the whole process to succeed, students need to be able to focus quickly on the concept in an interactive way that highlights the most common misconceptions.

It has been pointed out by teachers the benefits of teaching by questioning over the more traditional approach of teaching by telling (Green, 1998). Short and long-term improvement in student performance are a good sign that peer instruction in astronomy can give good results if it is well planned.

Conclusion

An astronomy course is an excellent way to convey to students the message of science, but the course must be well defined with fewer goals in order not to bore them. Our place in the Universe and how scientists work are two goals that astronomy can deal with best. Critical thinking and quantitative thinking are best approached by astronomy concept questions using peer instruction. This method of presenting the subject has been well accepted by our students and shows by the large numbers registering for our course.

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Chemical demonstrations: Science and theory

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Abstract

This paper is presented in conjunction with a demonstration lecture presentation, which was given during the conference in the Chemistry Laboratories at The Petroleum Institute. It was felt that the conference proceedings was an ideal opportunity to present a discussion on the benefits of chemical demonstrations rather than a list of recipes. For specific advice regarding demonstrations presented during the conference, the reader is advised to contact the author directly.

Introduction

The teaching of chemistry is fraught with challenges. The mere mention of the subject often conjures up dread in students and ex-students alike. In the media, 'chemical' is a dirty word, evoking concepts such as environmental damage and harm to human health. And yet we are surrounded by chemicals, the food we eat, the drugs we use to cure ourselves, and the commodity products that make our modern life possible. A great deal of this irrational fear can probably be traced back to chemistry classes at school. However, some non-chemists remember a different experience of chemistry. They enjoyed it even if they fail to understand it, and have a much more favourable view of chemistry. When asked, without fail, these adults stated that the reason that their chemistry experience was so good was the memorable demonstrations that stunned them at the time.

The challenge that is chemistry

Chemistry is a difficult subject to learn. As chemists we make no apologies about that. The overriding concept which needs to be understood is atoms and electrons. Since these are too small to see, hold, or feel, one must discuss chemistry as an abstract subject. Models help, but all students have to develop abstract thought processes in order to succeed. However, abstract thought processes, as described by Piaget, require time to develop. Since Piaget believed that abstract thought processes only develop when a subject is put in a position of disequilibrium, it is often the case that for many students abstract thought processes only develop during the teaching of a chemistry course. Again, this is another reason why students find chemistry difficult as a subject.

Coupled with this difficulty is the integrated nature of the subject. Unlike many other subjects, one cannot compartmentalise topics. If one could do this, one would be able to memorise the subject. Instead, success in chemistry depends upon the ability of the student to understand the logical thought processes needed to solve a particular problem. Once this is achieved, the student can then apply the rules to novel situations. For many fields of life, this is probably the most important transferable skill that the study of chemistry develops. However, whilst this process is occurring, the student finds chemistry to be immensely challenging and it is very easy, as a consequence, for him or her to become demotivated. And yet, within chemistry we possess the potential to incite wonder and amazement, to stimulate the imagination, provoke discussion, and to make the effort worthwhile and rewarding. I refer of course to the opportunity within chemistry to perform chemical demonstrations of chemical principles.

Shakushiri (1983), in the introduction to his texts on *Chemical demonstrations* describes how chemical demonstrations can have a quantity called ‘charm’, which depends upon: the size of audience, the specularity of the reaction, or the implied likely demise of the teacher!

How to perform stimulating demonstrations

A chemical demonstration as a part of a lecture class can be an excellent way to reinforce the learning of a concept. However, it is vital that the demonstration be relevant to the lecture material. In order to be able to teach the curriculum, one should aim for only one demonstration per class, which should be no more than five minutes long. Any longer and one risks ‘losing’ the students and wasting class time.

Teachers usually cite the following reasons why they do not perform demonstrations: a lack of time, a lack of resources or demonstration ideas, and a lack of confidence coupled with worries about safety. Each of these areas have several complex issues which must be addressed for success.

Lack of resources or lack of ideas

Chemistry is one of the more expensive subjects to teach, and consequently many science departments are under-funded. If this is an issue, one should try to present justification based upon the small additional cost, mostly the specialist chemicals required, against the quite considerable benefit to a student’s education. Unless one is highly proficient in the art of chemical demonstrations, I would strongly advise against inventing one’s own demonstrations. There are many excellent books (Shakhashiri, 1983; Becker, 1994; Ealy and Ealy, 1995; Royal Society of Chemistry, 1996) devoted to the subject and some excellent websites (best found by Googling ‘chemistry demonstrations’). Often, a demonstration can be quite benign and repeatable, but a slight change in proportions, purity or procedure can result in catastrophic accidents. One good example of this is the thermal decomposition of ammonium dichromate (the volcano demonstration). Small samples burn nicely, producing a large cloud of green ‘ash’, but larger quantities e.g. <20 g (as often happens when encouraged by the students to repeat the demo but bigger and better), have been reported to explode. Therefore strict obedience to the recipe is highly advised.

Lack of time

It is true that chemistry teachers are extremely busy people and have heavy time pressures. However, when deciding whether to perform a demonstration, one should include an analysis of the benefits to the students and oneself. A good demonstration is not only an excellent teaching tool, but can also be enjoyable to perform in front of the class. The better the rapport and motivation of the students that can be achieved will result in a much more harmonious atmosphere, reducing one's stress, and making the teaching a more pleasant experience.

Lack of confidence and fears about safety

Many teachers of chemistry have understandable fears about performing demonstrations, but it has already been discussed that, provided one follows a recipe pretty closely, the demonstration performs as expected and repeatably. However, to overcome nerves, one must make time to perform the demonstration beforehand. Ideally, get a colleague to observe the demonstration. Often a knowledgeable audience can offer ideas on improving delivery.

More importantly, there are genuine fears about safety. All demonstrations should be assessed for chemical hazard and risk, and appropriate control measures adopted. An example risk assessment procedure has been presented by the author elsewhere (Rostron, 2006).

One should start by considering the venue. Is there adequate ventilation, or should one move the class to a laboratory? Are there secondary exits? Fire extinguishers should be to hand. One should consider the minimum safe distance for the audience and consider the wearing of safety glasses. Whilst this might seem a bit onerous, remember that demonstrations are also an excellent opportunity to discuss the need for risk assessment and to show how, professionally, one should approach risk assessment. Many people still equate hazards with risk, and one should be able to show that one can safely deal with hazardous situations without the need to eliminate the hazard.

Worries about the audience

Unfortunately, these days a significant minority of students can be a disruptive influence on the group dynamics. Sometimes a whole group of students can have discipline problems. Many teachers of chemistry rightly refrain from allowing these students to perform experiments. In my experience, however, it is exactly those students who could benefit from a good demonstration. A spectacular demonstration can have a powerful motivating effect, and if one could inspire these students, the discipline problems may be mitigated. However, one must consider safety and therefore if necessary remove the disruptive student on safety grounds during the demonstration. This can also be a powerful motivating force because if one explains that the student has been removed because of his behaviour on grounds of safety, they may agree to modify their behaviour for future demonstrations. If handled well, and with sensitivity, emphasising that it is the behaviour that is unacceptable, the 'carrot' of demonstrations becomes an excellent behaviour modifier.

Conclusion

Chemical demonstrations require a lot of effort on the part of the teacher and their technician, yet have an extremely positive influence on student motivation and understanding. Being presented with hard facts generated in front of their eyes is one of the main methods of generating disequilibrium, encouraging the students to accept the underlying theory as correct. This acts as a concrete reinforcer in the development of abstract thought processes. Once a teacher begins a programme of demonstrations they find that the benefits in improved student motivation and understanding make the whole process worthwhile.

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Enhancing the motivation of Limited English Proficient introductory physics students by activity-based instruction

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Abstract

Alienation is a major concern with Limited English Proficient (LEP) students when the language of instruction is English; failure rates can be unacceptably high even in contexts where the LEP students should pass comfortably with only a modest amount of effort. I report on interactive engagement of LEP students in an introductory Electricity and Magnetism course; this course, with its reliance on sophisticated mathematics, intimidates even the best students. Lecture hours are divided into three (usually) *mini-lecture/Work Sheet* cycles. The five to ten minute *mini-lecture* introduces a single concept or formula. The associated *Work Sheet* (in simple, pared-down English with heavy reliance on graphics) requires the student to tackle a series of conceptual, graphical or symbolic questions; students are paired with their nearest neighbour and encouraged to discuss their answers. I roam the classroom monitoring progress, feeding hints to student pairs who are stuck. When enough pairs are finished (two-thirds or so), I select a completed *Work Sheet* at random; the answers are written up on the board, discussed and corrected (if necessary). Examples of quantitative problems are not worked in class. Instead, students in fixed groups of four solve (and hand in) a few judiciously chosen problems in a weekly one hour tutorial. Where appropriate, photocopies of the solutions of students are presented (on an overhead projector) in lectures. Preliminary indications are that these procedures, which can be implemented without any changes to existing classrooms, have a positive effect on student motivation levels.

Introduction

For many years, I subscribed to a maxim of the historian Edward Gibbon, author of *The decline and fall of the Roman Empire*:

The power of instruction is seldom of much efficacy except in those happy dispositions where it is almost superfluous.

Significantly (for a physicist), this quote is to be found in Richard Feynman's Preface to the celebrated *Feynman lectures on physics* (Feynman, Leighton and Sands, 1963). There can have been few more animated, inspiring or gifted lecturers of physics than Feynman and few environments more conducive to serious study than the California

Institute of Technology (Caltech). However, as Feynman ruefully concludes in his Preface, his lecture course was, in his opinion, a failure given the performance of the majority of students in examinations. What chance then do less talented teachers working at less selective institutions have?

One pragmatic response is being discussed at METSMaC 2007: courses based on the notion of *active learning*. Feynman himself may well have approved. In the above-mentioned Preface, he asserts that

...the best teaching can be done only when there is a direct individual relationship between a student and a good teacher — a situation in which the student discusses the idea, thinks about things, and talks about things. *It's impossible to learn very much by simply sitting in a lecture, or even by simply doing problems that are assigned.* But in our modern times we have so many students to teach that we have to try to find some *substitute for the ideal*. (My italics)

Active-learning courses can be a credible substitute for this ideal inasmuch as they promote a continuous discourse between a student and the teacher and, as important (if not more so with LEP students), between students. The interaction ensures that a student's grasp of the material under consideration is immediately challenged (in a non-threatening manner); the teacher can respond to bolster a student's confidence or correct (at least partially) the ideas of the student as they are being formed; fellow students can assist and, in turn, benefit from their attempts to explain their ideas to their peers: all-in-all, the seed is sown for further constructive processing of the content of a lecture after its completion.

Several introductory physics courses incorporating active-learning have been developed at colleges and universities in the US over the last fifteen years or so. Not surprisingly, definite improvements in student performance have been found (e.g. Hake, 1998). Consensus on successful approaches seems to have been reached and now efforts are being made by pioneering teachers and lecturers to reach out to the community at large; a prominent initiative is the *Physics Suite* produced by the Activity-Based Physics (ABP) Group.¹ As yet, these developments have had very little impact on instruction at my institution, but not for want of experimentation on my part. The biggest stumbling block is my students' limited proficiency in English, the medium of instruction.

What do active-learning courses on introductory physics comprise?

The book *Five easy lessons: Strategies for successful physics teaching* (Knight, 2002) contains an extremely useful introduction to active-learning in the physics classroom. Knight describes twelve different researched and tested approaches to promote active learning. What follows is my digest of Knight's digest (on pp. 49–61); whereas the

¹This group includes P. J. Cooney (Millersville University), K. Cummings (Southern Connecticut State University), P. W. Laws (Dickinson College), L. McDermott and P. Shaffer (University of Washington, Seattle), E. F. Redish (University of Maryland), D. Sokoloff (University of Oregon) and R. Thornton (Tufts University). The ABP Group homepage may be found at http://physics.dickinson.edu/~abp_web/abp_homepage.html; it gives details on *The Physics Suite* and Workshops run by the ABP Group.

headings below are Knight's, the summaries which follow highlight the points of most interest to me and are not necessarily representative of his descriptions.

1. Overview, Case Study (OCS) Physics (van Heuvelen, 1991a; 1991b)

There are no formal lectures: students work through Active Learning Problems Sheets (available as the ALPS kit); the Think/Pair/Share protocol is observed [see 7. below]. The course is divided into a few blocks (Newtonian mechanics is an example of a block); the sequence *Qualitative Overview* → *Quantitative Problem-Solving* → *Case Study* is followed within each block.

2. Cooperative Groups (Heller, Keith and Anderson, 1992; Heller and Hollabaugh, 1992)

Mixed ability groups of three (formed by the teacher) solve *context-rich* problems in tutorials; to control behaviour in groups, students have roles (Manager, Sceptic, Recorder); these change each week and, after three weeks, groups change. A *context-rich* problem is stated within a short story, which motivates the problem and, usually, includes irrelevant information but does not specify the unknown (and may omit some information).

3. Socratic Dialog Inducing (SDI) Labs (Hake, 1987; 1992)

SDI Labs comprise simple physical activities (such as pushing a block) coupled with questions which expose misconceptions; because of their simplicity, these labs can be performed by students in lectures or in tutorials.

4. Microcomputer-Based Labs (MBLs) (Thornton and Sokoloff, 1990; 1998; Sokoloff, Thornton and Laws, 1999)

Very effective laboratory experiments based on *real-time* acquisition and display of data; the focus is on phenomena instead of measurement. In many cases, students must first predict what will happen.

5. Interactive Lecture Demonstrations (Sokoloff and Thornton, 1997)

An *interactive* lecture demonstration *engages* the students: when an outcome is not obvious, the teacher lists conceivable outcomes and makes each student write down a prediction, then conducts the demonstration and discusses the implications of the outcome for a sample of the predictions; when the outcome is obvious, students working in pairs calculate the expected size of the result. (*Vernier Software* sells a package called *Interactive Lecture Demonstrations*, a sample of mechanics MBLs.)

6. Peer Instruction (Mazur, 1997)

Each hour lecture is divided into three (or four) *mini-lecture/ConcepTest* cycles; there are strictly controlled amounts of time for each portion of a cycle; example problems are not solved in class (because of the time taken by *ConcepTests*). The *ConcepTest* is a short multiple-choice *conceptual* question (on a transparency) tied to the mini-lecture (which focuses not on definitions or derivations but on concepts, reasoning and intuition); the Think/Pair/Share protocol is observed [see 7. below]; student answers are polled anonymously (using *Classtalk* or Flashcards); in an optimum *ConcepTest*, 40 to 60 per cent of student answers should be correct. Depending on the answers of the class, a second *mini-lecture/ConcepTest* cycle on the material may be presented. Students are expected to read the textbook to learn material not covered in lectures;

study of the textbook is enforced by Reading Quizzes (at the beginning of each lecture). Examinations need to include *ConceptTest*-like questions.

7. Think/Pair/Share (TPS)

In this less structured (but more flexible) version of *Peer Instruction*, the teacher poses a question, students THINK about it individually and write down a response and, only then, SHARE and discuss their answer with their nearest neighbour; the teacher polls the class by asking what a few different PAIRS think (or by a show of hands). There are many sources for Think/Pair/Share material: Interactive Lecture Demonstrations; conceptual questions like those in *ConceptTests*, exercises from *Student Workbooks* accompanying research-based physics texts, 'Physics Jeopardy' questions (van Heuvelen and Maloney, 1999); *individual* steps in a structured problem-solving strategy (like van Heuvelen's OCS method).

8. Ranking Tasks (O'Kuma, Maloney and Hieggelke, 2000)

These are exercises which could be used with *Peer Instruction* or *Think/Pair/Share* (or in examinations); the focus is on conceptual issues.

9. Tutorials (Shaffer and McDermott, 1992; McDermott, Shaffer and Somers, 1994; McDermott, Shaffer and the Physics Education Group, 1998)

The tutorials of McDermott's Physics Education Research Group (integrating pre-tests, worksheets and homework assignments) lead students through a series of conceptual and graphical questions which correct misconceptions. Students interact with peers on worksheet exercises and receive teacher feedback at each stage.

10. Workshop Physics (Laws, 1991; 1997a)

Drastic reorganisation is required. Students meet for three two-hour periods per week in a laboratory; pairs of students work through the many varied activities in the *Workshop Physics Activity Guide* (Laws, 1997b) with occasional mini-lectures by the teacher; extensive use is made of computers and MBL tools for data acquisition, video capture and analysis. The teacher-to-student ratio is high, which means that the approach is only appropriate to small institutions.

11. Studio Physics (Wilson, 1994)

Studio Physics resembles *Workshop Physics* but is designed to work with a larger number of students at a large university. Two-hour classes take place two or three times a week in a *studio* (a classroom containing thirty computers); students (two per computer) sit with their backs to the teacher, but can swivel round to face the teacher. Instruction uses computer-interfaced experiments and other computer tools, but there is more emphasis on problem-solving and computation than in *Workshop Physics* and more mini-lectures. Implementation requires training of teachers and lecturers alike.²

²The *Studio Physics* approach has been developed for large enrollment classes as *Technology Enabled Active Learning (TEAL)* at MIT and as *Student-Centred Activities for Large Enrollment University Physics (SCALE-UP)* at North Carolina State University and elsewhere. For descriptions, see <http://icampus.mit.edu/projects/TEAL.shtml> and <http://scaleup.ncsu.edu>. The staff-to-student ratio is lower: a class of fifty students can be administered by one member of staff and one teaching assistant.

12. Research-based textbooks

Knight identifies four texts for calculus-based courses. His own (Knight, 2004) and those by Chabay and Sherwood (2002a; 2002b), Moore (2003) and Reif (1997). To this list should be added the ABP Group's text (Cummings, Laws, Redish and Cooney, 2004). All of these books encourage active learning.

Local adaptation

My opportunities for implementing active learning in the introductory physics courses at my institution are severely constrained. Each of these courses is taught by a large team of teachers following a fixed syllabus and using a textbook selected by the department with examinations drawn up by intrinsically reactionary committees. Our lecture venues are designed for conventional 'chalk 'n talk' presentations; although many rooms have recently been fitted with screens and projectors (of various kinds), the infrastructure for lecture demonstrations or hands-on activities in class is not in place. However, in my opinion, the most fundamental obstacle is the students' limited proficiency in English, the language of instruction.

For many students, lectures delivered in English are incomprehensible. Almost all of our students struggle to compose even the most basic of sentences and would be overextended if asked to write a paragraph. Few, if any, are able or prepared to read the prescribed text. Occasionally, some of the better students can be induced to dip into the textbook to extract specific information; typically, conscientious students only use the book to look at the end of chapter (EOC) problems which are assigned for practice or homework. Crucially, students often fail to understand the English (not the physics) in examinations and tests, despite the fact that they are prepared in very simple language.³

Under the circumstances, efforts to introduce active learning into physics classrooms at Kuwait University (KU) may seem futile. I, nevertheless, entertain the belief that KU and American students have enough in common to warrant some attempt at innovation inspired by the success of active-learning techniques in the US. The reading habits of KU students may not be all that dissimilar from those of their American counterparts. The Preface to the research-based text *Understanding Physics* (Cummings, Laws, Redish and Cooney, 2004) contains the following lament:

We know from surveys that the vast majority of introductory physics students do not read their textbooks carefully. . . they develop strategies for passing physics without spending time on careful reading.

The strategy KU students adopt is to memorise solutions to past examination papers in the (justified) hope that much the same problems will reappear in their examinations. This type of behaviour is only too familiar to American educationalists:

³These claims about reading are based on something more compelling than informal observation of student behaviour over the years. For three years (beginning in the summer of 2001), I issued handouts to my students containing complete summaries of my lectures (which followed the textbook very closely) and EOC problems taken from the textbook; both the lecture summaries and the EOC problems were translated into the kind of stripped-down language used in our examinations and tests. It was my hope that students would do more reading *before* examinations and tests and so struggle less *during* examinations and tests. Significantly, students ignored the lecture summaries but snapped up the problem sheets.

To novices, ‘learning’ physics simply means memorisation of information and of problem-solving recipes that apply to highly specific situations (Wieman and Perkins, 2005).

Incidentally, KU students protest that physics is too difficult and made more so by the way we teach and examine it. Intelligent American students agree: according to physics student Eric at the University of Arizona,

... already hard subject matter is made even harder and more frustrating by the pedagogy itself” (Tobias, 1990).

With some classes at KU (especially those for men), the sense of alienation from the first day onwards is almost palpable.

My first tentative pedagogic innovations were not successful. To begin with, I experimented with a few *ConceptTests* from Mazur’s *Peer Instruction* (Mazur, 1997) in an introductory mechanics course for fifty pre-medical students (without restructuring lectures into *mini-lecture/ConceptTest* cycles). How would the students respond? I chose a class of pre-medical students for two reasons: their command of English is better than that of our other students; at the time, only their examinations included multiple-choice conceptual questions. I came to learn first hand why Mazur advocates anonymous polling of student answers: once the novelty of *ConceptTests* had worn off, not enough students were prepared to participate in the show of hands which I required to ascertain their answers. Some students were unsettled by their inability to answer correctly the ‘simple’ questions in *ConceptTests*; many felt that class time would be better spent solving quantitative problems (which made up two-thirds of the final examination). I concluded that half-measures would not do.

The next semester, I expanded the scope of my endeavours with a class of about thirty male students taking the introductory Electricity and Magnetism (EM) course. I did not try to adhere to Mazur’s tightly orchestrated *mini-lecture/ConceptTest* regime, but, from day one, I broke up my hour-long lectures with *ConceptTest*-style questions (at the expense of some worked examples) and I introduced reading assignments along with reading tests (for some topics of less importance). It soon became apparent from the almost randomly chosen answers to reading tests that students were not taking the reading assignments seriously; about halfway through the course, I dispensed with the reading assignments and texts. Usually, there was no more than one *ConceptTest* question per lecture. At first, I used the conceptual questions in *Peer Instruction* (Mazur, 1997), but, later, I relied more heavily on end of chapter questions from the textbook for the course, namely *Fundamental of Physics* (Halliday, Resnick and Walker, 2001). Instead of polling student answers by a show of hands, I distributed ‘Concept Test’ sheets on which students had to write down their answers (and student identity numbers) which I then collected. The Think/Pair/Share protocol could not be enforced: many students would do nothing until they could consult their partner, when they merely copied their partner’s answer; there was little or no discussion between pairs. Much to my chagrin, there was no obvious improvement in the students’ attitude towards the course nor, more importantly, in their overall performance (compared to previous years).

Having failed with a TPS-like methodology in lectures, my next initiative involved the weekly hour-long tutorial in the introductory EM course. Could students be en-

couraged to use the time to solve problems for themselves rather than watch a teacher solve them? It occurred to me that this may be feasible if students were allowed to work in groups and if the problems were written in the very simple English used in our examinations.

In the spring semester of 2006, I decided to try out these ideas with the fifty-one female students enrolled in my class of the introductory EM course. I arbitrarily fixed the number of groups to be eight and so limited the amount of marking of solutions to manageable proportions. Using the students' performance on prerequisite courses as a guide, I formed groups of approximately equal strength, but, in the second week, I allowed the handful of students who were uncomfortable in their allotted groups to change places with members of other groups: the priority was that the members of a group should be prepared to collaborate. I based most of the problems on EOC problems assigned for homework by the course conveyor. In rewriting the EOC problems, I broke them down into a sequence of instructions, one for each step. I felt that this would help the students and coax them to develop sound working habits (like the drawing of diagrams, the algebraic rearrangement of formulae and the consistent use of vector notation); it certainly made marking the students' solutions easier. I also created problems which were more closely connected with what I had covered or was about to cover in lectures. In fact, I tried to make the relation between a tutorial and the lectures immediately before and after it as seamless as possible. Often, the solution to a problem was a natural starting point for the next lecture; invariably, to heighten the students' awareness of the importance of what they were doing in the tutorials, I would present and discuss photocopies of their solutions on an overhead projector in the week following a tutorial.

The effect of these measures on student morale was remarkable. Enforcing attendance of tutorials was not a problem, a first in my time at KU. For the students, the tutorials were something different and, dare I say it, enjoyable. It is true that because the groups were too big, many students sat and chatted while others did the work, but most of the students with poor marks on prerequisite courses thrived. As the semester progressed, more and more of the disaffected students came on board; by semester's end, only two or three remained unconverted. I came to see my primary role as that of motivator. If I could instil in the students the belief that they could do well, they would put in the effort to ensure that they did. And 'my' girls did!

Emboldened by this success, I have returned to the issue of the effective use of time in class. My current working hypothesis is that the TPS approach I employed earlier failed because the male students I was teaching simply did not understand enough of my spoken English. How could the brain teasers from *Peer Instruction* or *Fundamentals of Physics* have any appeal to students in this predicament? Under the circumstances, an appropriate course of action would be to abandon formal lectures.

This is what I have done in teaching introductory EM to male students in the autumn semester of 2006. My students have spent class time on *Work Sheets* covering the most important topics in the syllabus. The *modus operandi* is described in the abstract. Two points need to be emphasized: I have tried to keep the *mini-lecture* which precedes the distribution of a *Work Sheet* as brief as possible; the primary purpose of most *Work Sheets* is to get the student to comprehend material not apply it. The weekly tutorials have been run as in the previous semester but with smaller groups (most with four

members, a couple with five). The final examination has still to be written at the time of writing. However, through the semester, the students have performed significantly better than any other class of males I have taught at KU.

Conclusion

After some trial and error, I believe that I may have succeeded in adapting some active-learning techniques to the teaching of physics at Kuwait University. It will be interesting to see whether the improvements witnessed in student performance persist over the next few semesters.

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Microsoft Excel in the physics classroom

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Abstract

With the high demand for hands-on activities and a limited amount of space and equipment, it is often difficult to give all students adequate hands-on experience during the traditional two- or three-hour physics laboratory. This situation can be partly handled by doing physics simulations. Microsoft Excel is a powerful application that can be used to perform simulations and achieve student learning outcomes. Using Microsoft Excel, it is possible to integrate the three domains: theoretical, experimental and computational. Exploitation of a powerful spreadsheet-oriented technique in teaching and reinforcing the physical concepts has further enabled us to integrate information technology into the physics curricula. In this paper, we discuss our 'experiments' with Excel in the physics laboratory and in the classroom.

Introduction

The use of computer technology in the experimental sciences has facilitated the way physicists, engineers, chemists, mathematicians, and many others are able to acquire and analyse large amounts of experimental data. There are numerous hardware and software programs available for this purpose. One of the objectives of an introductory science laboratory course is that the students become proficient in using computer technology for analysing data. Therefore, providing the science student with a proficiency in using computer technology to analyse data in the laboratory will be a very valuable skill that will certainly benefit them in their future careers. There are several possible approaches in using computers in the physics curriculum, ranging from using ready-made packages to using a programming language. The former yields results but the learning is usually minimal. In the latter case it requires a lot of training to write the algorithms in a programming language. Such expertise is usually not available with students taking the introductory physics courses. Spreadsheet programs are powerful programming and graphical analysis tools that can be applied to a variety of problems in the sciences. The spreadsheet approach provides a middle course between the ready-made packages and the programming languages such as FORTRAN or C++ and is more suited for learning.

Spreadsheets have a very interesting history (Power, 2004). We opted to use Microsoft Excel because it is widely available, easy to use, and meets our objectives. In

this article, we shall briefly look at the history of spreadsheets and their advantages. Then we shall describe our experience of using the Excel in the physics laboratory and in the classroom. We had a very rewarding experience when we introduced Microsoft Excel into our mathematics curricula (Al Rawahi, Khan and Huq, 2006).

Spreadsheets and their advantages

Spreadsheets have been used by accountants for hundreds of years. Computerised or electronic spreadsheets are much more recent. In the realm of accounting jargon a spreadsheet was and is a large sheet of paper with columns and rows that organises data about transactions for a business person to examine. It spreads or shows all of the costs, income, taxes, and other related data on a single sheet of paper for a manager to examine when making a decision. An electronic spreadsheet organises information into software defined columns and rows. The data can then be 'added' by a formula to give a total or sum. The spreadsheet program summarises information from many paper sources in one place and presents the information in a format to help a decision maker see a more complete picture.

In 1961, Richard Mattessich pioneered the development of computerised spreadsheets for use in business accounting. These operated on the mainframe computers. The widespread use of spreadsheet programs had to wait until personal computers became common. Spreadsheets made their first appearance for personal computers in 1979; this was the VisiCalc, created by Dan Bricklin and Bob Frankston for the Apple-II platform. It was conceived and developed as a tool to do repetitive calculations for Bricklin's studies at Harvard Business School. The name VisiCalc is a compressed form of the phrase visible calculator. The basic paradigm of an array of rows and columns with automated updates and display of results has been extended with libraries of mathematical and statistical functions, accompanied with powerful graphing facilities (Bricklin and Frankston, 1999). VisiCalc was succeeded by Lotus 1-2-3. It incorporated integrated charting, plotting and database capabilities. Lotus 1-2-3 established spreadsheet software as a major data presentation package as well as a complex calculation tool. In 1984, Microsoft came up with its own version of the spreadsheet program called Excel. When Microsoft launched the Windows operating system in 1987, Excel was one of the first application products released for it. Now Microsoft (MS) Excel has superseded all other spreadsheet programs. It was one of the first spreadsheets to use a graphical interface with pull down menus and a point and click capability using a mouse pointing device. MS Excel spreadsheet with a graphical user interface makes it very attractive for users. Moreover, MS Excel has established itself as a ubiquitous program.

Electronic spreadsheets such as MS Excel can be used effectively in education and science. MS Excel is readily available and one need not buy costly packages. MS spreadsheets are easy to use enabling a middle course compared to the extreme of coding an algorithm in some programming language (such as FORTRAN or C++) or using a ready-made package. The spreadsheet approach is more suited for learning. Moreover, MS Excel has a highly developed graphical interface with an in-built help module. Beginning students can do statistical analysis (calculation of mean, median, mode, standard deviation, etc.) of data and make a graphical presentation (pie charts, bar charts, etc.). Students can also do many complex mathematical operations (includ-

ing topics such as applied calculus) using MS Excel with ease. Excel enables numerical analysis in an easy and lucid manner requiring no prior knowledge of computer programming. Presenting information in graphical form is useful in studying many phenomena in science. Excel is a very useful tool in analysing data collected in the laboratory and on field trips.

Using Excel can enhance understanding of content within a graphic presentation of the information. It provides a visual representation of data that makes it easier to analyse. Excel reduces the difficulty of plotting data and allows students a means for interpreting the data. Excel can easily convert any chart or data set into a web-page, making it very easy to share information among groups. Excel's ability to dynamically generate charts and graphs in seconds makes it easy to quickly demonstrate relationships between numbers. As a teaching tool, students can see how different types of graphs and charts can be used to represent the same series of data. A major advantage of an electronic spreadsheet is that it can be stored (in devices such as CD's and flash-memories) and re-used later. Moreover, the stored data can be used for a comparative analysis (Khan, 2007).

Data analysis using Microsoft Excel

Microsoft Excel enables us to tabulate and analyse data collected while performing experiments. Here we shall discuss the experiment of measuring the acceleration due to gravity g using a simple pendulum.

A simple pendulum consists of a mass (bob) hanging from one end of a string. The string is considered to be of negligible mass in comparison to the system as a whole. The period of one complete swing (oscillation) T and the length ℓ of the pendulum are related to the acceleration due to gravity g by the following equation

$$g = 4\pi^2 \frac{\ell}{T^2}.$$

In an experiment one varies the length of the pendulum and measures the corresponding period of oscillation. The two variables associated with this activity are the length of the pendulum and the period of oscillation. The length is the independent variable and the period of oscillation is the dependent variable. The value of acceleration due to gravity is around 9.81 m s^{-2} varying from place to place. It is interesting to note that this important constant can be reproduced to very high accuracy by using a simple pendulum. The length of the pendulum is measured along with the corresponding period of oscillation. Since it is difficult to measure the period of one oscillation (typically one to two seconds) directly, we measure the time for ten oscillations. This measurement is made two or more times to minimise measuring errors and then their average is taken. Table 1 shows the data recorded together with the corresponding calculations performed.

The period of oscillation T in column E is calculated by averaging the data in columns C and D and then dividing by ten. The subsequent calculations in the columns F–H are relatively straightforward and we shall not elaborate on them. Column H gives the values of the acceleration due to gravity g for various choices of the length of the pendulum. We compute the average value for g in this column, which turns out to be

	A	B	C	D	E	F	G	H
1								
2			Simple Pendulum					
3								
4	S No.	Length L	Exp-1 10 Swings	Exp-1 10 Swings	Average Period T	T^2	$4\pi^2 L$	$g = 4\pi^2 \frac{L}{T^2}$
5	1	0.17	8.26	8.2	0.823	0.677329	6.711331	9.908524501
6	2	0.22	9.32	9.43	0.9375	0.87890625	8.6852519	9.881886574
7	3	0.27	10.43	10.4	1.0415	1.08472225	10.659173	9.826637881
8	4	0.32	11.34	11.16	1.125	1.265625	12.633094	9.98170361
9	5	0.37	12.18	12.05	1.2115	1.46773225	14.607015	9.952097538
10	6	0.42	13.17	12.93	1.305	1.703025	16.580935	9.736166757
11	7	0.47	13.78	13.68	1.373	1.885129	18.554856	9.842751489
12	8	0.52	14.4	14.35	1.4375	2.06640625	20.528777	9.934531098
13	9	0.57	15	15.21	1.5105	2.28161025	22.502698	9.862638911
14	10	0.62	15.67	15.62	1.5645	2.44766025	24.476619	10.00000671
15	11	0.67	16.34	16.37	1.6355	2.67486025	26.45054	9.888568867
16	12	0.72	16.84	16.78	1.681	2.825761	28.424461	10.05904628
17	13	0.77	17.28	17.31	1.7295	2.99117025	30.398382	10.16270523
18	14	0.82	18.02	18.15	1.8085	3.27067225	32.372302	9.897751886
19	15	0.87	18.6	18.58	1.859	3.455881	34.346223	9.93848553
20	16	0.92	19.37	19.19	1.928	3.717184	36.320144	9.77087607
21	17	0.97	19.59	19.65	1.962	3.849444	38.294065	9.947947047
22	18	1.02	20.36	20.28	2.032	4.129024	40.267986	9.752422353
23							Average g	9.908041574

Table 1: Data for the oscillating pendulum.

9.90 m s^{-2} . This is in excellent agreement with the accepted value of 9.81 m s^{-2} . The data can also be presented graphically. By plotting the length ℓ versus the reciprocal of the square of the period $1/T^2$ a straight line of best-fit can be drawn and its gradient used to determined. One can similarly analyse the data generated from related experiments in the pendulum series: variation of mass of the bob, variation of the swing angle.

Concluding remarks

MS Excel is extremely useful in analysing data collected from an experiment. In the preceding section we described the analysis for a simple pendulum for a demonstration purpose. In a similar fashion it can be used for numerous other experiments. MS Excel is much more efficient. MS Excel is readily available on many computers. This saved us from incurring additional costs in buying software. We could plot many more graphs and concentrate much more on the experiments without worrying about the data analysis. Exploitation of a powerful spreadsheet-oriented technique in teaching and reinforcing the physical concepts has further enabled us to integrate information technology into the physics curricula. We need to exercise some caution while using Excel. One can easily make mistakes while entering the formulae into Excel. One can miss a few cells while highlighting the data entries and during the drag operation. To overcome such errors it is good to use the traditional calculator approach for a few random values. We are in the process of exploring the automation of some of the experiments widely performed in an introductory physics laboratory using MS Excel. If we achieve this, it will be of immense help in generating quick results during on-site field measurements where time is a key factor.

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Online physics homework for engineering students in the United Arab Emirates

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Abstract

It is widely acknowledged that, to learn physics a student must practice thinking through and working out well-designed problems, and that this demands a significant investment of time and effort. Because of this, teachers typically assemble and assign problem sets as homework. Students, working singly or in groups, produce hard-copy solutions that are handed in, marked by the teacher, and finally returned. There are imperfections in this traditional scheme: students can simply copy the work of others (missed learning opportunity); there are long delays in returning marked work (ineffective feedback); and, marking work is very labour intensive (loss of teacher time). In Core Physics at The Petroleum Institute we have begun using an online homework service to overcome these limitations. We are using the University of Texas Homework Service, provided free-of-charge to legitimate users. Internet-based homework systems, like the University of Texas service, provide students with individualised homework problems, immediate feedback upon submission of answers, multiple attempts for credit, and computer-generated individualised solutions after the deadline. Based on the first semester of use, written student questionnaires show a mixture of views, but with the majority of students showing a preference for traditional physics homework. The stated reasons for their preferences, however, indicate some of the advantages of online homework and support its future use.

Introduction

During the autumn semester of 2006, Core Physics at The Petroleum Institute (PI) in Abu Dhabi, United Arab Emirates (UAE), implemented the large scale use of online homework in their two introductory physics courses, *Physics I – Mechanics* (PHYS 191) and *Physics II – Electromagnetism and Optics* (PHYS 241). Prior to this, one of us (Bradley) used online homework, primarily from the University of Texas (UT) Homework Service,¹ for several years at a US university and then used it for two semesters at the PI with students in his classes. Based on this experience, Core Physics at the PI

¹Details are available from <https://hw.utexas.edu/bur/overview.html>. Clearly, access to large sets of homework solutions must be controlled. Because of this, user legitimacy is determined and monitored by University of Texas staff.

decided to use the UT service for this trial. In this paper, we briefly discuss the various online homework options that currently exist, describe what it takes to use the UT service, what we did to implement and evaluate online homework, and what we have learnt.

Context

This paper has evolved out of an ongoing effort to improve teaching and learning effectiveness for introductory physics courses at the PI. A major part of learning physics is practice in problem solving. Since problem solving requires time and effort to learn, it is frustrating for a significant fraction of students. In this context, our students are given problems and their work is subsequently marked by lecturers and assigned credit, typically amounting to five to ten per cent of the final course mark. Students are also frequently reminded that mental effort properly invested through homework is typically rewarded by better test performance and significantly higher course grades. Despite these efforts, and regardless of the precise form of the assignments, teachers have generally been dissatisfied with how much our students learn from the problem sets. One problem with traditional homework is that marked papers do not provide timely feedback for student learning. Also, as our students are typically very helpful to each other, the stress of homework deadlines often leads to copying of solutions and a consequent significant undermining of the learning potential or meaningful assessment value of assigned work. In Core Physics at the PI, this issue is viewed as our most significant teaching challenge.

Overview of online physics homework

The development and use of online physics homework is driven by multiple factors. A central goal is to substantially increase and improve what students learn from doing homework. Despite the hope for significantly improved learning, research indicates that, on average, online homework by itself does not produce much of an impact, either positive or negative (Bonham and Beichner, 2001). Not surprisingly, there is also evidence that learning gains from online homework can result when it is in combination with other course elements such as improved student attendance and teaching that promotes active student engagement (Pollock, 2004).

This last decade has seen tremendous growth in online homework options. Homework engines (the software that generates and delivers the questions) are becoming increasingly powerful. Online homework typically consists of questions with variable text and graphics so that students must provide unique or ‘individualised’ answers. Answering formats range from multiple-choice and fill-in-the-blank questions with text or numerical answers, to questions that require students to manipulate images or draw using their computer mouse. There are currently four major options for online physics homework: two that are non-commercial university systems and two commercial services. Also, there are new forms of online homework which may contribute even greater learning gains for students.

There are currently several non-commercial online homework options. The UT Homework Service was started in 1997 and remains a university-supported, university-

maintained, non-commercial service. A similar system is available from Michigan State University called LON-CAPA (Learning Online Network Computer-Assisted Personalised Approach).² This system, started in 1992, is an open-source, learning management software package that can be freely downloaded and locally installed (similar to Moodle,³ for example). The package contains an ‘assignment engine’ for delivery of online homework that is automatically individualised for each student. The LON-CAPA homework is similar to what is available from the UT Homework Service but it is more interactive, with limited hints and suggestions for students and, importantly, an integrated threaded-discussion for each problem. The threaded-discussion supports postings (named, anonymous, or by screen names) which encourage student vocalisation of difficulties and supports online peer tutoring. It also can provide useful feedback for lecturers (Kortemeyer, Hall, Parker, Minaei-Bidgoli, Albertelli, Bauer and Kashy, 2005). Unfortunately, LON-CAPA does require a local computer (server) to host the online interactive homework web pages.

There are also several commercial alternatives for online physics homework. The most basic are textbook-derived problem sets that may be imported into many commercial course management systems as so-called ‘e-packs’ or digital publisher content. These tend to be in the form of quiz-like, multiple-choice question databases. Better commercial alternatives are WebAssign⁴ and MasteringPhysics.⁵ WebAssign was originally started by North Carolina State University in 1996. It is an online course management service with an assignment engine much like what is available from UT or the LON-CAPA system. WebAssign’s primary advantage is a very large question database derived from common (and recent) textbook editions. MasteringPhysics is a relatively new commercial homework service, with a commercial start date of 2005. It was developed at the Massachusetts Institute of Technology and, in its early forms, was called ‘CyberTutor’ and later ‘myCyberTutor’. MasteringPhysics provides online homework (and other course tools) like the others, but it is much more sophisticated. It can provide many problems that are structured as tutorials with a high level of feedback, hints and suggestions, sub-problems and detailed explanations for students to learn from. Furthermore, MasteringPhysics provides an increased level of detailed information to the teacher about class performance on assigned problems and detailed results of individual student work too.

Since research and development in this area is ongoing, we should expect more sophisticated online homework options in the near future. Clearly, the development of online homework is rapidly moving away from simple right-or-wrong feedback and traditional ‘end-of-the-chapter’ type problems toward highly interactive tutorial problems that exploit computer simulations and game-like interaction. Research in tutorial-style online physics problems is limited but the early results already show some promise. An example is the Andes Physics Tutor,⁶ developed at the University of Pittsburgh and now currently available free-of-charge for use online⁷ via the Open Learning Initiative from Carnegie Mellon University or as a downloadable non-web version. The Andes

²<http://www.lon-capa.org/index.html>

³<http://moodle.org>

⁴<http://www.webassign.com>

⁵<http://www.masteringphysics.com>

⁶<http://www.andes.pitt.edu>

⁷<http://www.cmu.edu/oli>

system is a set of problem-solving tutorials that can be assigned and computer-marked as homework. The tutorials require students to explicitly demonstrate their problem-solving steps by selecting objects, setting up coordinate systems, declaring and defining values and variables, typing in equations, drawing vectors, and picking choices from menus. A five-semester evaluation (autumn semesters from 1999 through 2003) of the tutorials was conducted at the US Naval Academy (VanLehn, Lynch, Schulze, Shapiro, Shelby, Taylor, Treacy, Weinstein and Wintersgill, 2005). This study indicated significant improvement in student learning, as demonstrated by performance gains on tests and end-of-course examinations. A proposal for an online tutorial that goes further in this direction, is to try to make more explicit certain qualitative analysis skills (such as the use of multiple representations) that are commonly employed by expert problem solvers and not by novices (Greene, 2006). Also, more sophisticated tutorial systems have been demonstrated for teaching conceptual physics ideas using natural language dialogue between the student and the system. The most recent examples of this have animated conversational ‘agents’ that dialogue with human-like tutorial ‘moves’ based on latent semantic analysis of student-typed responses and programmed pedagogical strategies (Jordan, Makatchev, Pappuswamy, VanLehn and Albacete, 2006). Conceptual learning gains from this form of tutoring appear promising, at least from an initial small-scale study (Graesser, Jackson, Mathews, Mitchell, Olney, Ventura, Chipman, Franceschetti, Hu, Louwerse and Person, 2003).

The University of Texas homework service

The service provided by the University of Texas (UT) has been growing and freely available for use during the last ten years. It is currently used by students from middle-school level to university-level across the US and internationally. Homework problems are available in mathematics, biology, chemistry, computer science, physical science, and physics. For example, in 2005 the total number of problems available was: 10 000 for physics, 11 000 for mathematics, 7500 for physical science, 6700 for biology, and 15 600 for chemistry. In 2005 the service supported a total enrolment of 118 000 students and processed an average of over one million answer submissions per week. See the university’s website for more details of the service’s history.⁸

The basic functionality of the UT service for teachers and students is a free service providing computer-marked homework with numeric or multiple-choice response items comparable to end-of-chapter textbook problems (in fact, the majority of the problems were obtained directly from textbooks). The only requirement is that teachers and students have some access to the Internet and can print out the assignment pages. The service is designed to encourage students to spend time with the problems on paper and not sitting and interacting with a computer screen. This approach allows use of the online system for teachers and student users with lower bandwidth Internet connections or dependence on shared computers.

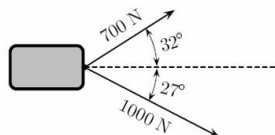
The service provides detailed online documentation, complete problem solutions, record keeping, and various reporting tools to display student assignment grades in several formats, and various summaries of student performance on individual problems or assignments. Teachers control student enrolment but students register themselves for

⁸<https://hw.utexas.edu/bur/history.html>

the service. Assignable problems in the service's database are organised by subject and level into 'books' which can be viewed online or downloaded as PDF files by lecturers. At least in physics, the problems are organised into topic sections comparable to most texts coming out of the US. For each assignment, teachers select and arrange the problems, view the solutions, set the deadline, and finally 'post' the problem set online. Students access the online service by password, download and print out their homework assignment (online time of a few minutes) and then work on their problems offline. Once they have answers, they log back onto the service, submit answers online, receive immediate right/wrong feedback on submitted answers (again, being online a few minutes). They can (and do) rework and resubmit answers for initially incorrect submissions to earn partial marks on those items. After the deadline, students can download and print detailed solutions.⁹

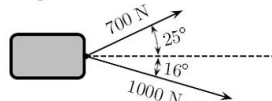
A key feature is that many of the problems are algorithm-driven. They use random numbers, strings, and figures as parameters (variables) so students are assigned the same generic problem but receive unique versions (their answers are different depending on the parameters in each version of the problem). An example¹⁰ is shown in Figure 1. Here, two versions of the same problem are given together for comparison.

Two men decide to use their cars to pull a truck stuck in mud. They attach ropes and one pulls horizontally with a force of 700 N at an angle of 32° with respect to the direction in which the truck is headed, while the other car pulls with a force of 1000 N at an angle of 27° with respect to the same direction.



What is the net forward force exerted on the truck in the direction it is headed?
Answer in units of N.

Two men decide to use their cars to pull a truck stuck in mud. They attach ropes and one pulls horizontally with a force of 700 N at an angle of 25° with respect to the direction in which the truck is headed, while the other car pulls with a force of 1000 N at an angle of 16° with respect to the same direction.



What is the net forward force exerted on the truck in the direction it is headed?
Answer in units of N.

Figure 1: Example of two student versions of one assigned algorithmic physics problem. In this case just two quantities are variable, the angles of each applied force. The example also shows the typical two-column layout of typeset-quality printed assignment sheets.

The above example illustrates the basic advantage as well as the limitation of this type of online homework. The advantage is that while students can help each other, direct copying of answers is strongly discouraged; the answers for the left and right questions are not the same. The limitation is that one student can read his question, work out that the answer is given by $F_1 \cos \theta_1 + F_2 \cos \theta_2$, and then share this result with his friends in the class. Still, many of the problems are a bit more complex and so require multiple reasoning steps. In such cases, it is more difficult for students to simply 'give' answers as formulae to each other.

⁹<https://hw.utexas.edu/bur/functionality.html>

¹⁰<https://hw.utexas.edu/bur/problemVersions.pdf>

Other limitations of the service, also illustrated by the above example, are more subtle. For a numerical question, as in the figure, the student is given the answer's physical unit (here the Newton) and need only provide a number. Some teachers would prefer to have students provide values and units. A second issue is that sometimes a problem's text and figure shows parameters with only one or two significant figures (here the angles are given with two significant figures) while the computer scores answers based on three significant figures (to be scored correct an answer must be within one per cent of the computer's answer). Some lecturers see this as contrary to what we should be teaching; students are being encouraged to treat all given numbers as exact regardless of their expressed form. The authors of the UT system provide a good explanation (defence) of their approach¹¹ with regard to significant figures and neither of these issues really turns out to be much of a problem, if students and teachers are aware of them early on.

Implementation of online physics homework at The Petroleum Institute

To start, lecturers and students had to learn some new work routines. This had to be handled with care in order to minimise the stress and confusion for everyone involved. For individuals who are not particularly Internet- or computer-savvy, getting started with online homework can be a bit daunting. Teachers needed to get oriented at least a few weeks in advance of student access. In our case, we had six lecturers who individually set up their own online homework assignments for their own classes. The following is a summary of what we did (and what others would need to do to provide this type of online homework) combined with advice gained from our collective experience.

The lecturers first needed to request access to the UT system, set up their individual online course, and create their first online homework assignment. To request access, each lecturer must register¹² (using the first two steps in the linked page). Next, each lecturer created a class (unique for their students and their assignments), set up or approved the marking-grading scheme for his class, and created a first assignment from the problem books. For convenience, we decided it was best to download local copies of the appropriate books as PDF files. To create an assignment a lecturer simply copied the exact titles of selected problems (it was easiest to electronically copy and paste them from the PDF problem book) into an online form, then select the marks assigned to each problem, and the time and date the assignment would be due. Before posting the assignment (the last step) it turned out to be a good idea to download (i) the lecturer's version of the assignment (including solutions), and (ii) the range of student answer values for each assigned problem. Some lecturers gave this second item to their students to help them catch simple and common errors (such as often occur in unit conversion or neglect). With that preparation, the lecturers were ready to get their students started with the online homework.

While most students adapted easily to online homework, others found it a challenge at first. To help the transition to online homework, we spent one class period in a campus computer laboratory introducing students to the online homework. For this

¹¹<https://hw.utexas.edu/bur/significantFig.html>

¹²<https://hw.utexas.edu/bur/instrGuestEID.html>

introduction, each student sat at an individual Internet-connected computer and followed a printed start up procedure. Lecturers typically showed what the various web pages looked like on an overhead screen and then kept busy circulating in the laboratory to assist individual students. During this period, the set goals for students were to (i) enrol themselves in the UT system and the lecturer's online homework course roster, (ii) become familiar with the online course structure, (iii) download and print out their first problem set, and (iv) submit their first answers online and receive immediate computer feedback about these answers. Most students were able to complete all four goals in the time provided. The first step was the most complicated. For the UT system, there is a lengthy application process for students to be enrolled (as students get an UT electronic identification called a UT EID). While a handful of students completed the process without help (some even doing it before coming to class that day), it was critically important that teachers (and other peer students) were available to guide most students through the numerous online application pages.

After that first critical day of real use, students and lecturers still had more learning to do about the online homework system. Of course, as with any complex process or machine, most of the confusion could be eliminated if teachers and students took the time to carefully read the instructions.¹³

Specifics of the trial

In the autumn semester of 2006, all PHYS 191 and PHYS 241 classes at the PI were given some online homework assignments with some other form of homework. The non-online homework was usually traditional exercises done on paper, derived from or similar to end-of-chapter problems. For the following discussion, we will refer to online homework as web-based homework (WBH) and traditional homework as paper-and-pencil homework (PPH). This terminology comes from the paper by Dufresne and co-authors (2002). To determine how students viewed these two types of homework, all classes for PHYS 191 and PHYS 241 were given an in-class survey (see Appendix – Physics homework survey) near the end of the semester. The results of student responses are summarised in the following section.

The survey asks students to assign grades to the types of homework they had received based on how challenging and effective it was. They also rated the level of effort that they gave the homework and then gave an overall grade for the quality of the homework. These terms are defined on the survey and also were briefly discussed as the survey was handed out in class. Finally, students were asked to write out what type of homework they thought was best, to give a reason for this, and to make any additional comments.

In all, there were seventy-three students in PHYS 191 and fifty-eight students in PHYS 241. In all but one section, students did at least half of their assignments online. In one section of PHYS 241 (sixteen students) only a few assignments were given online, so this section constitutes a group with 'low exposure' to WBH. We will discuss and compare the results from the low-exposure group separately from the results based on the rest of our data. In PHYS 241, we obtained a total of forty-seven completed surveys (twelve in the low-exposure group). In PHYS 191, we obtained fifty-seven

¹³<https://hw.utexas.edu/bur/studentInstructions.html>

completed surveys. A secondary complication existed in PHYS 191 due to differences in the form of the PPH component. For two-thirds of the students, the PPH consisted mostly of traditional sets of end-of-chapter problems (or similar problems). For one-third of PHYS 191 students, the PPH consisted of non-traditional question sheets that were either about textbook reading assignments or work done with computer simulations. Results from this difference, summarised in the following section, turned out to be a very striking.

Results

First, given the small numbers of students involved and the lack of controlled comparisons, we must acknowledge that our results are tentative. Still, we do see some trends worthy of discussion that are based on differences in the homework experiences of our students and the types and variation of survey responses.

We hoped to determine if students regarded the online homework as too difficult since the grades they received from WBH were (in some classes) approximately ten per cent lower than for PPH assignments and since several lecturers recognised that they tended to select somewhat more challenging WBH problems than they selected for PPH. Finally, and most importantly, we wanted to know how students would compare the effectiveness of these forms of homework – Did students think the WBH helped them learn physics better than traditional homework?

First, using the open-response question on the surveys, we immediately find that more than two-thirds of surveys indicated preference for traditional PPH over WBH, as shown in Figure 2. This trend is consistent for PHYS 191 and PHYS 241 students. For PHYS 191 students who were alternately assigned WBH and non-traditional PPH assignments, the trend was reversed, the strong majority preferring the online assignments.

The reasons students cited for the above written preferences were categorised and tabulated. These are shown in Figure 3. We show four groups: PHYS 191(T) students who preferred WBH over traditional (T) PPH, PHYS 191 students who preferred traditional (T) PPH over WBH, PHYS 241 students who preferred WBH, and PHYS 241 students who preferred PPH. The percentages show the frequency of the comment category within the surveys in one of these groups. Since students sometimes made several comments (or no comments) the percentages do not add up to one hundred per cent.

Overall, the most common comment had something to do with the ‘content’ of the problems. Despite the high frequency of these comments, no clear WBH/PPH distinction emerges from this category. The next two frequently cited reasons for student preference had to do with the assignment being ‘easier’ or helping with ‘learning’. What is striking is that only students preferring traditional PPH cited ‘easier’ as being their reason in both PHYS 191 and PHYS 241. ‘Easier’ was never cited as a reason for students who preferred WBH. Looking at the frequencies of ‘learning’ type reasons for preference, it appears to be a stronger factor for students preferring WBH than for those preferring PPH, by more than double. Clearly, some students preferred traditional PPH due to the technical problems and hassles of online homework (shown by the ‘glitches’ category). Finally, a significant number of students who preferred WBH referred to its impact on student copying.

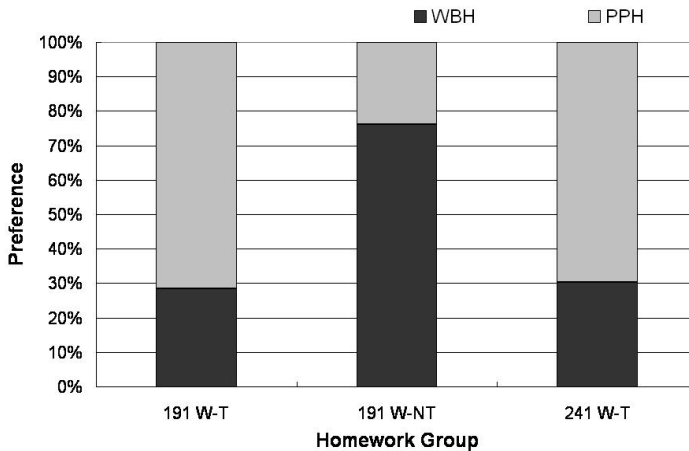


Figure 2: Fractions of surveys showing student preference for various types of physics homework. The left-most and right-most bars show that approximately seventy per cent of students prefer traditional (T) paper-and-pencil homework (PPH) over web-based homework (WBH). The trend is reversed for students who had non-traditional (NT) PPH with WBH.

In addition to the stated preference and reasons for this preference, students graded the various types of homework according to difficulty, effectiveness, overall quality, and their own effort. Students gave letter grades with A, B, C, D, or F (converted to a scale from 4.0 to 0.0) corresponding to the levels of the homework difficulty (‘extremely challenging’ to ‘never challenging’), effectiveness, quality, and their effort expended, as described on the survey. The resulting average grades along with standard errors are shown in Figure 4. The results are grouped by type of homework and student class: WBH for PHYS 191 students (191W), traditional PPH for PHYS 191 students (191T), non-traditional PPH for PHYS 191 students (191NT), and so on.

First, examining the differences for 191W and 191T ratings, it is clear that the grades do not seem to support the strong preference difference shown earlier. The one significant difference is a somewhat higher effectiveness for traditional PPH over WBH (the difference equal to three-fourths of a letter grade). What is more striking is the comparison of these two assignment types against the non-traditional PPH. Clearly, students did not, on average, consider these assignments as challenging, effective, or high in quality, and they did not put as much effort toward them either. Clearly future investigation is needed to understand this difference; it is strong (one letter grade) and consistent with the preferences shown in Figure 2, but it is complicated by the fact that the non-traditional homework involved two distinct activities (textbook reading and computer simulation use).

Next, looking at the contrast between WBH and PPH for PHYS 241 students, it is clear that WBH was seen as more of a challenge but not as effective for learning. The

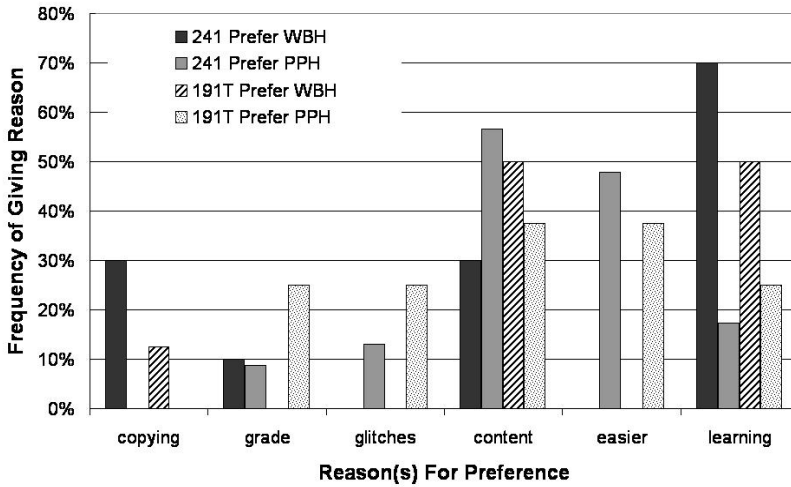


Figure 3: Frequency of reasons cited for overall homework preference among students in PHYS 191 and 241 who compared traditional PPH and WBH.

comparative judgement of difficulty is consistent with the finding that students who preferred PPH often did so because they considered it as easier. No student cited this as a reason for preferring WBH. The rating of effectiveness, however, is inconsistent with the cited reasons for student preferences. Students who preferred WBH cited improved learning as a reason more than three-times as often as students who preferred PPH.

Lastly, we will mention and discuss the main result from the low-exposure group. These students universally preferred PPH over WBH. A possible explanation for this is that WBH requires new work routines and therefore it is likely that there is a kind of threshold for attitudes as students and teachers adapt to online homework. WBH is not something that can easily be tried for just a few assignments and then reliably judged.

Conclusions and further work

The results of our survey are consistent with our expectations, except for the anomalous reaction of students to the non-traditional PPH homework. Students preferred traditional PPH over WBH by two to one. The dominant reason cited for this preference was that students found WBH more difficult. Students who did prefer WBH, more often cited its effectiveness for learning than did students preferring PPH. Clearly, these online assignments did help with student learning and did interfere with copying.

Based on lecturers impressions and the results discussed above, Core Physics at the PI decided to continue its use of online homework. Current and future work will continue to explore student attitudes regarding physics homework and its impact on

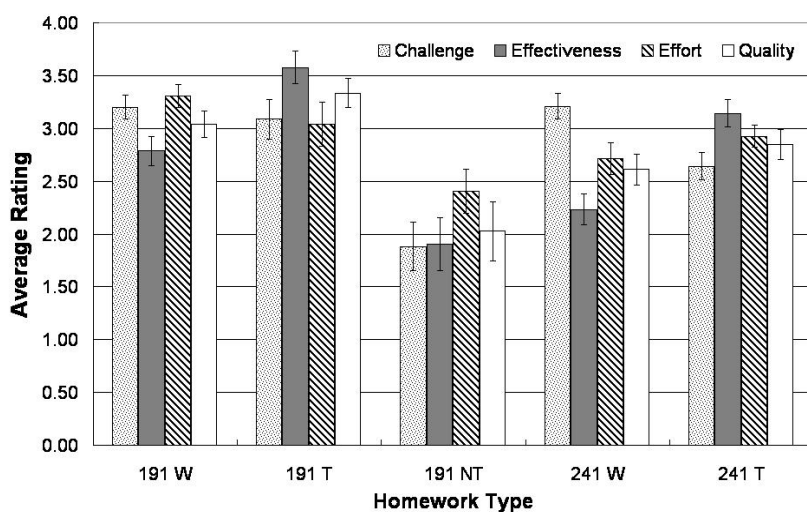


Figure 4: Average student ratings of homework types in terms of level of challenge, effectiveness, the effort expended by the student, and the overall quality of the homework in terms of effectiveness and effort needed.

learning. The department will also look more carefully at the interesting issue of reading assignments and assignments based on student use of simulations. Finally, future studies will explore the evolution of attitudes about online homework during a second semester of use.

Appendix – Physics homework survey

This is a survey. It will not affect your final mark in the course. Results from this survey will inform our future decisions. Please evaluate the physics homework that has been assigned this semester. For each aspect and type of homework, please determine a grade from A to F (defined below):

Grade	Challenge	Effectiveness	Effort and Quality
A	Extremely challenging	Extremely helpful	Excellent
B	Very challenging	Very helpful	Very good
C	Challenging	Helpful	Average
D	Somewhat challenging	Somewhat helpful	Below average
F	Never challenging	Not helpful	Unsatisfactory

Item	Definition
Challenge	Did this type of homework challenge you to think, learn, and practice skills?
Effectiveness	Can this type of homework help you learn physics and prepare for examinations?
Effort	Rate your typical effort on this type of homework.
Quality	Overall, was this type of homework helpful and worth the effort?

Assign a grade for each	Online questions and problems	Chapter reading assignments	Physics simulation assignments
Challenge			
Effectiveness			
Effort			
Quality			

Which type of homework is best? Why? Any other comments?

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Phyziks is Phun: A modest collection of simple demonstration experiments which are sure to delight

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Abstract

It is sometimes said that while mathematics is the queen and servant of all science, physics is king. The collection of demonstration experiments described in this paper will attempt to show that physics can also be fun and entertaining as well. Many of the demonstrations make use of ideas proposed, studied and documented throughout the last two millennia. Some of the described demonstrations will appear to be both simple and obvious, while others will be more thought-provoking and even counter-intuitive. In all, an appeal to simplicity is made.

Introduction

There seems little doubt that the study of introductory physics is a difficult undertaking. Many students often choose not to study physics given the perception it has for being demanding. Its apparently simple concepts turn out to be subtle yet deep and are often contrary to many students initially held notions. Furthermore, the already difficult concepts are typically presented laden under excessive mathematical baggage which only tends to further obscure them. Researchers continue to discover what good teachers of physics have always known – the concepts of physics are not intuitively obvious and are not transmitted to students by simply telling them (Swartz, 2006). Fluency in the understanding of physical concepts which are either unfamiliar or counter-intuitive to the beginning student requires a maturity of mind and years of experience in handling the given phenomenon. One such way the development towards fluency in conceptual understanding can be made, particularly for physics taught at the introductory level, is with instruction that couples simple demonstration experiments with more traditional lectures and problem-solving tasks (Sorensen, Churukian, Maleki and Zollman, 2006).

As we have done in the past (Stewart, 2005; Stewart and Dirks, 2006), the demonstration experiments chosen were based on selections that not only highlighted simplicity and elegance, but also have an ability to demonstrate a surprising or unanticipated result. Demonstrations that were improvements or modifications on previously known

experiments were also sought. Finally, all selected demonstrations are taken from topics typically covered in an introductory physics level course.

On the virtues of an ideal demonstration experiment Taylor (1988) writes that each demonstration selected for performance should be simple, have strong visual appeal, and should make its scientific point so that it is at once clear without the need of complicated justifications or explanations. We could not agree more. Here transparency in the equipment used, and in their performance, are key – magic black boxes and intimidatingly complex apparatus are best avoided.

A good demonstration experiment should lift the veil on concepts and phenomena which are not intuitively obvious and where words alone are of little help. They should also, wherever possible, point the way to what lies beyond since the unknown is often never far removed from the simplest of phenomena (Swartz, 2006). While a good demonstration experiment can be spectacular, one should not lose sight of their intended purpose which is to aid learning and understanding within the student and not to merely entertain. Choosing demonstration experiments solely for their ability to wow an audience should be avoided if one is not prepared to discuss the underlying physics with one's class (Macdonald, 2006).

Recent research suggests that demonstrations presented to a passively observing audience do little to improve conceptual understanding in students and pedagogically may as well not have been performed used at all (Crouch, Fagen, Callan and Mazur, 2004). Instead, student learning is most enhanced by increasing student engagement. The performance of any demonstration should be preceded by an appropriate description of the equipment being used and a brief explanation of the phenomenon one wishes to demonstrate. In order to promote anticipation and constructive debate, students should have the opportunity to predict the likely outcome of the demonstration or be given a limited set of likely possibilities to choose from (here the use of an electronic polling system using, for example, so-called 'clickers', is indispensable for such a task). On performing the demonstration, multiple times wherever possible, its outcome should be carefully observed. Discussion follows and the outcome of the demonstration should be related back to student predictions. Finally, a brief summary of what was actually observed indicating how the demonstration relates to the particular phenomenon under consideration should be made. This is something which is often overlooked by the teacher but is vitally important if the connection between concept and reality is to be made by the student.

A good and continued source of demonstration experiments remains the professional society publications from the Institute of Physics (IOP) and the American Association of Physics Teachers (AAPT) in the form of their journals *Physics Education* and *The Physics Teacher*, respectively. For those who read either German or Portuguese, the journals *Physik in unserer Zeit* and *Revista Brasileira de Ensino de Física* have both proven useful. Finally, the ever growing source of a range of short video clips of demonstration experiments to be found on websites such as *Google Video*¹ or *YouTube*² have also proven to be useful sources of inspiration.

¹Available at: <http://video.google.com>

²Available at: <http://www.youtube.com>

Simply simple

Simple demonstration experiments using common and readily available materials are often the best. With no expensive and obtrusive equipment to get in the way, the path is cleared for better understanding of the underlying physical concepts and encourages students to repeat such experiments in their own time away from the formal classroom setting.

Pipe circular motion

The single most difficult idea for students to grasp in uniform circular motion is the initially counter-intuitive idea that objects move off tangentially when the centripetal force acting on the object is removed, not radially. One way to demonstrate this effect uses a cut-away end section of a PVC pipe with an inner diameter of about 10 centimetres together with a steel ball-bearing or marble. A small section at one end of the pipe is removed by cutting a notch large enough for the ball-bearing to pass through. The other end remains intact. With the intact end positioned on an overhead projector and the ball-bearing inside, the latter is given a gentle flick and circular motion is observed on the screen as the ball-bearing traverses around the inner walls of the pipe which provides the centripetal force. If the pipe sitting on the overhead projector is now inverted so that the end containing the notch is facing downwards, flicking the ball-bearing once more leads to it moving around the inner wall before leaving tangentially to the pipe through the opening and is clearly visible from the projected shadow provided by the overhead projector. See Zetie (2006) and Ehrlich (1997, 2.1, pp. 22–23) for further discussion or Mitschele (1998) for details of a simple calculation on the minimum size in the opening required for the ball-bearing to pass cleanly through the pipe.

Free fall drop

An alternative to the classic demonstration of a feather and coin falling freely at the same rate inside an evacuated glass tube can be performed in air. Take a large book and a single sheet of paper which does not extend beyond any of the edges of the book. Hold the two side by side and at the same height above ground level before dropping each simultaneously. It will be noticed that the sheet of paper falls much slower to the ground compared to the heavy book since it is noticeably affected by the effects of air resistance. Now take the sheet of paper and place it on top of the book. On dropping, both fall at the same rate and reach the ground together. Students, however, usually remain unconvinced since they believe the book has somehow aided the sheet of paper's downward descent by 'pushing' the air out of its path. Finally, to overcome any lingering doubts, crumple the piece of paper up into a tight ball and drop the book and ball of paper from the same height at the same time. Since the surface area of the sheet of paper has been considerably reduced, the effects of air resistance on the paper are also greatly reduced and each will roughly reach the ground at the same instance and demonstrates that each object falls at the same rate irrespective of its mass. See van den Berg and van den Berg (2001) or Sprott (2006, 1.1, pp. 2–5) for further details.

A simple polariscope

Some optical materials which are not normally birefringent (have different indices of refraction for different directions of polarisation) become so when subjected to mechanical stresses and strains resulting from induced optical anisotropies within the ma-

terial. An optical instrument used to investigate mechanical stresses and strains arising in transparent models of certain objects of interest is called a *polariscope*. Here the usually complicated stress distribution in the object shows up as colour interference patterns by passing linearly polarised light through the optically anisotropic material and viewing it through an analyser. Liquid crystal displays (LCDs) used for modern flat-screen computer monitors, being large and reasonably bright, are an excellent source of linearly polarised light. This can be readily confirmed by holding a polaroid sheet, for example the lens from a pair of polaroid sunglasses, up to the LCD screen and slowly rotating it. The transmitted light will be seen to change from half of the screen intensity down to zero. Positioning a range of transparent objects in front of the LCD screen, such as the transparent front cover of a compact disc jewel case, a glass tumbler, clear plastic framing, etc., and viewing each in turn through a polaroid analyser, colourful interference patterns related to the stress pattern in each object will be observed. Flexing each object while it is being observed results in the form and position of the colourful interference pattern changing as the stress pattern within the object changes. For large audience viewing within a classroom setting the interference patterns are best viewed by holding the lens from a pair of polaroid sunglasses over the aperture of a computer connected webcam and projecting the resulting image onto a large screen using a data projector. See Lewowski (2006).

Water temperature and density

Most students will be familiar with the notion that warm air rises while cool air sinks. One way this phenomenon can be visually demonstrated is by changing the fluid used from air to water. In a fish tank filled with water at room temperature place two water filled bottles on their side so that each lays next to one another and both lay immersed on a ledge in the fish tank. In one of the bottles is red food-coloured water from a hot tap while in the other is blue coloured cold water which has been sitting in an ice bath. If the lids from each of the immersed, coloured water filled bottles are carefully removed, after a minute or two a blue streak of water from the opening of the first of the bottles to the bottom of the fish tank and a red streak from the opening of the second bottle to the top of the water surface will be seen. Here the warm red water, being less dense than the surrounding water, rises while the cool blue water, being more dense than the surrounding water, sinks.

The homopolar motor and its evolution

Simple electric motors are always sure to please. The homopolar motor, the first motor ever invented in the early nineteenth century by the eminent experimental physicist Michael Faraday (1791–1867), differs from most modern-day DC motors in that commutators are not required to reverse the direction of current flow in order to maintain continuous rotation in the same direction. Recently, interest in this very old form of motor has been revived due to the ease and simplicity with which such motors can be built and operated. All are sure to intrigue and fascinate students and colleagues alike and are some of the most elegant and beautiful demonstrations ever conceived.

Simple homopolar motors

The cheap and ready availability of very strong permanent magnets in the form of rare-earth magnetic alloys such as neodymium-iron-boron, so-called neodymium magnets,

has recently revived interest in the design and development of ever simpler forms for the homopolar motor (Chiaverina, 2004; Schlichting and Ucke, 2004). In its most recent form one side of a small neodymium disc magnet is stuck to the level head of a ferromagnetic screw. The screw, in turn, becomes magnetised owing to the strength of the neodymium magnet. The pointy end of the screw can now be stuck to the bottom terminal of a 1.5 V D-cell battery where it hangs freely under gravity since the battery's casing is ferromagnetic and provides a very low friction connection between the hanging magnet and the battery. If one end of a copper wire is pressed against the top terminal of the battery using your finger, brushing the other end of the wire against the rim of the disc magnet completes the circuit and not only causes current to flow but leads to a spinning in the disc. Two surprising features of the motor that are sure to amaze onlookers is the readiness with which the disc magnet rotates, and the size of the final rotation speeds achievable. Understanding what causes the disc to rotate provides students with an excellent example of the application of the right-hand rule used to determine the direction a magnetic force acts on a current-carrying conductor in the presence of an external magnetic field. On brushing the wire up against the outer periphery of the disc, current flows from the rim to the central connection point at the head of the attached screw. As the disc magnet itself now takes on a current-carrying function, a Lorentz force acts tangentially to the inwardly flowing radial component of the current in accordance with the right-hand rule. The resultant torque causes the disc to spin about its attached axle.

A number of modifications to the above arrangement are possible and seem to be limited only by the imagination and ingenuity of teacher and student alike. In one such modification the total number of basic elements required for the motor can be reduced to three and changes the component of the motor which actually rotates (Featonby, 2006). By bending the copper wire into a frame which takes on the approximate shape of the letter M and extending its base into a pair of horizontal arms parallel to one another, the frame is supported by positioning the cusp in the middle of the M-frame on the flat negative terminal of a battery. With the positive terminal stuck to a large cylindrical neodymium magnet³ such that the battery's position as it sits on the table is inverted, compressive forces within the connecting M-frame ensure its horizontal parallel arms press up against the magnet. This completes the circuit. Current flows and causes the connecting wire to rotate as a current-carrying wire is now in the presence of an external magnetic field.

A second similar design, though a little more visually striking, is to fashion the connecting wire into the shape of a helical spiral that runs down the length of the battery. Both of these latter two designs result in an operation of the motor which is completely hands-free and with a total of three components used; one has to ask, are these not the simplest motors in the world?

A simple homopolar roller

A more recent incarnation of the homopolar motor using neodymium magnets is of the rolling type. While not a completely new idea in itself it was Sugimoto and Kawada (2006) who showed most elegantly how the former spin of the simple homopolar motor could be made to roll. This was achieved by sticking two neodymium disc magnets to

³Our magnet used was 25 millimetres high and had a diameter of 20 millimetres. A stack of smaller disc magnets could be used in place of one single, large, cylinder magnet.

either terminal of an AA battery. The electric circuit was then completed by placing the entire arrangement onto a flat conducting surface (or conducting rails) from where it was observed to roll. Torques act on each of the disc magnets in a manner identical to those described for the homopolar motor with the exception that the conducting surface replaces the connecting wire. In order to get both of these torques to act in the same sense it is necessary to orientate each end magnet so that like poles face one another. As ingenious as Sugimoto and Kawada's homopolar roller is, it suffers from two significant drawbacks. Firstly, getting the double disc magnet and battery arrangement to roll over a conducting surface is difficult since one needs to ensure good electrical contact between the two. Secondly, once the roller is in motion, final rolling speeds attainable are significantly impeded by the effects of magnetic braking resulting from eddy currents induced within the conducting surface itself. Both of these problems, however, can be overcome if the arrangement were to roll over a non-conducting surface. If the circuit between the rims of the disc magnets is completed using a short, non-ferromagnetic connecting U-shaped wire, sufficient electrical contact between the upper rim of each disc magnet and the wire can be maintained as it rolls by moulding either of its ends into an arc of a circle (Stewart, 2007). As the circuit is now complete, current flows over the ends of the disc magnets and results in magnetic forces acting on either wheel. Provided the connecting wire is placed on the side of the roller behind its forward direction of motion, the resultant torques which act cause the double disc magnets and battery to roll off with the U-shaped wire trailing behind. On a smooth, flat surface the homopolar roller can roll at a comfortable walking pace over a reasonable distance before the connecting wire becomes dislodged. As a variation, instead of the roller using the disc magnets as its wheels, if disc magnets whose diameter is less than the diameter of the battery are attached to either terminal and the circuit is once more completed using a U-shaped connecting wire, this arrangement with the battery now in contact with the ground can be made to roll along a smooth surface. In this latter configuration, however, the speed at which the roller rolls is greatly reduced.

Analogue demonstrations

Analogue demonstrations, those experiments which use '... a phenomenon whose behaviour is sufficiently similar to [what is] being discussed to make it valuable as an instructional aid' (Taylor, 1988, p. 63), play an important part in helping to develop and aid understanding in phenomena that are otherwise difficult or inaccessible to perform within the normal classroom or laboratory setting.

Playing-card soliton

Solitons are very stable solitary waves which do not broaden, break up or lose strength while propagating in a dispersive medium. The first documented soliton was observed in 1834 by John Scott Russell (1808–1882) who while riding on horseback saw and followed one for several miles before it finally outpaced him and his horse along Union Canal near Edinburgh, Scotland. Nowadays, solitons are ubiquitous in nature and can be found in a variety of systems ranging from water and sound waves to electromagnetic and charge-density waves. One simple way to model a single soliton is with several decks of playing-cards. With the decks stacked together, spread them out in a straight line along a reasonably rough surface, such as over a tablecloth, by pushing

and running your hand along the stack of cards. By lifting the last card at the bottom of the line of cards up with your index finger and moving it along the spread, cards gather up and group together by forming into a peaked, tent-like shape. Moving your finger quickly along the line, a wave is produced which does not dissipate as it moves such that a soliton is trapped permanently within the tent-like spread of cards. The interaction between a soliton and anti-soliton can also be modelled using the spread of playing-cards. If along the line of cards a small section to one end are overturned and lie in the opposite direction compared to the rest of the spread, the gap formed models an anti-soliton. Running the soliton into the anti-soliton results in mutual annihilation on meeting and is analogous to what happens when a particle collides with its corresponding anti-particle. This analogue demonstration for the soliton was inspired by Gardner (2002). For an experimental description and accompanying mathematical analysis of solitons in a wave tank filled with water, see Morton and Bingham (1989).

Cool physiks

The next set of demonstrations, which rely on the evaporation and condensation of a liquid, lay claim to a long and distinguished lineage.

Drinking bird heat engine

This is a very well-known physics toy which gives the visual impression of being a heat engine that works as a ‘perpetual motion’ machine, in direct contradiction to the second law of thermodynamics. So how does it operate? To start the drinking bird, it is necessary to tilt it about the horizontal rotation axis and wet the head and beak thoroughly, then allow it to return to its initial orientation. The drinking bird works by evaporation of the coloured ethyl alcohol (ether) contained within the lower bulb (reservoir) and evaporation of water from the damp felt-covered upper bulb which forms the head. The volatile ethyl alcohol inside the reservoir evaporates at room temperature and as it vaporises, the pressure in the lower bulb increases. At the same time water from the damp head evaporates, causing the vapour inside the head to cool and therefore reducing the vapour pressure. This creates a pressure gradient within the sealed system, which pushes the liquid up the connecting tube towards the head, resulting in a change of the position of the centre of mass of the whole system. As the vapour inside the upper bulb (the head) is being cooled by the evaporation of water from the outside of the head, some condenses back to a liquid, so there is a nett transfer of liquid from the lower bulb (body) to the upper bulb (head). After a short time, sufficient liquid has condensed inside the head to displace the centre of mass upward towards the head. As a result, the increasingly unstable bird overbalances and rotates about the horizontal axis by pivoting forward. When this happens, the pressure seal between the connecting tube and remaining liquid in the reservoir is broken, and as a result, the liquid that had condensed inside the head flows back down towards the body and at the same time vapour from the reservoir travels upwards until the pressure is equalised. The effect of the liquid flow is to displace the centre of mass downwards, which causes the bird to be rotated upright once again. The pivoting action tips the head towards a glass of water which wets the beak (which in turn wets the felt-covered head by capillary action), allowing it to subsequently cool again by water evaporation. This re-condenses the volatile vapour inside the head again – thus repeating the cycle over again, pro-

vided there is sufficient water available in the glass for the bird to dip the beak into and 'drink'.

The bird can be viewed as a thermodynamic heat engine that utilises a working fluid to exchange heat with two heat reservoirs and could perform useful mechanical work. The working fluid is the ethyl alcohol contained within the sealed system. It absorbs heat into the lower bulb at room temperature and loses heat during the evaporative cooling of the damp felt-covered head. The bird performs mechanical work by changing the gravitational potential energy of the liquid contained within the system. In normal operation, this potential energy is converted into rotational kinetic energy of the observed swinging motion. Clearly, a simple low friction electro-mechanical device could be designed to utilise the work that the drinking bird could do and then by appropriate scaling, drinking bird 'farms' could be established (perhaps using large scale birds for example) to generate electrical power! It should be noted, however, that on humid days, the above described motion would progressively diminish and eventually cease as the air becomes saturated with water vapour, and the evaporation stops. A further point to note is that if ethyl alcohol is used as a replacement for the water, the action of the bird is observed to be much quicker since the alcohol is far more volatile.

The second drinking bird demonstration (a waterless version that could be described as a drinking bird of the third kind) makes use of the standard version of the drinking bird, but with two major differences. Firstly, it is devoid of the usual appendages such as beak, tail and a felt-covered head and secondly, it is spray painted so that the large lower reservoir bulb is black (preferably matt black to make it as close as possible to an ideal thermodynamic 'black body') while the smaller upper bulb is painted white. With this design, the difference in absorption of radiant heat from the sun or a light bulb causes the required thermodynamic temperature difference instead of the action of evaporative cooling. The modified version now only requires a moderate source of heat in order to maintain the motion. For a detailed analysis of the physics involved in the drinking bird and other related experiments see Güémeza, Valiente, Fiolhais and Fiolhais (2003). For an interesting version referred to as a drinking bird of the second kind see Abraham and Palffy-Muhoray (2004).

Hand boiler

The so-called hand boiler resembles the well-known drinking bird physics toy but with three major differences. Firstly, it is not mounted on a horizontal axis (since it is not intended to oscillate freely), secondly, it is devoid of the usual appendages such as beak, tail, feet and a felt-covered head, and thirdly, it generally has a corkscrew-spiral (or otherwise twisted) section in the glass tube connecting the two bulbs. Initially, the liquid (ethyl alcohol containing a non-volatile dissolved dye) is entirely contained in the lower (larger) bulb that serves as a reservoir. When the lower bulb is held in one hand (or grasped between the palms of both hands), thermal expansion and the resulting increase in the pressure of the vapour above the liquid cause the liquid to flow vertically up the connecting tube from the lower bulb to the upper bulb. After a relatively short time, most of the liquid will have been transferred into the upper bulb. However, expanding vapour bubbles from the small quantity of residual liquid continue to rise up through the liquid in the spiral glass tube, giving the appearance of 'boiling'. In reality the liquid is not actually boiling, since for the liquid to boil, its vapour pressure would have to be equal to the pressure of the vapour contained within the upper bulb. The

small amount of heat from a hand is not sufficient to raise the vapour pressure to that level, but to an observer, the visual appearance suggests otherwise.

Hand boiler distillation

An interesting experiment can be performed using the hand boiler as a miniature closed system distillation apparatus. Firstly, ensure that all of the liquid is in the lower bulb (the large reservoir). Then, slowly (and very carefully) tilt the hand boiler so that it becomes horizontal. Invert the hand boiler so that the liquid remains in the large reservoir bulb (which now becomes the upper bulb). The smaller bulb that contains only vapour is now the lower bulb. Place the lower (smaller) bulb in a chilled container (ice cubes in water works very well) while at the same time holding the upper bulb with one hand (or grasped between the palms of both hands) as before. Finally, observe that the (essentially) colourless ethyl alcohol condenses in the smaller lower bulb and the non-volatile chemical dye remains in the upper reservoir bulb. This can be readily explained. As the vapour cools and condenses in the lower bulb due to the reduced temperature, the vapour pressure decreases. This causes more liquid to vaporise in the upper bulb, which then enters the lower bulb, cools, and subsequently condenses. The upper bulb becomes quite cold if touched, since liquid vaporisation is an endothermic process (evaporative cooling). Since the chemical dye is non-volatile, it remains in the upper bulb. Eventually, the entire vapour is condensed into the chilled lower bulb of the inverted hand boiler and the upper bulb contains only the dye. The two components are then separated and the distillation is complete! The theory is fine, however, in practice it is actually quite difficult to get all of the coloured ethyl alcohol out of the connecting tube (it can be accomplished more effectively and quite rapidly using a hairdryer as a source of warm air and directing it appropriately). Incomplete distillation will cause the condensed liquid to be slightly coloured, but the difference in colour will make it quite obvious that the concentration of dye in the two bulbs is different. See Becker and Becker (1996).

Hero(n)'s fountain

Hero of Alexandria (also known as Heron) was a Greek mathematician and philosopher who is variously described as living sometime between 150 BCE and 300 CE and is best known today for developing an important equation in plane geometry for finding the area of a triangle. He is known to have been the author of at least thirteen works on mathematics and principles of mechanics (primarily in the areas of hydraulics and pneumatics). As a result of his active and inquisitive mind he was instrumental in the development of many mechanical devices, including the aelipile (a simple rotary steam engine), and a gravity fed water fountain produced and sustained by air pressure (the device became known as Hero's fountain). Many of his mechanical studies can be read in the 1851 translation of his book *Pneumatica* (Woodcroft, 1851). Today you can find numerous publications, both written and on the Internet, which describe the design, construction and operation of several different modified constructions of Hero's fountain.

The demonstration version we describe here is one of the simplest forms, using two large (2.5 litre) plastic bottles, one of which is approximately half filled with water, plus a screw fit connector and some rigid plastic tubing (stiff drinking straws would be quite adequate). The operating procedure is as follows (assuming the apparatus has

been assembled and one of the bottles has been appropriately half filled with water). Firstly, allow the water to flow into one of the two bottles and then carefully invert the whole system so that the water can descend into the empty bottle (which is now the lower bottle). It will be observed that during this process, some water will emerge as an intermittent fountain from the plastic tube (straw) above the highest level of the water in the emptying upper bottle. This apparent paradox is resolved on closer examination of the apparatus. Passing straight through the screw connector that is located between the two bottles, there are two plastic tubes (straws). Close to the point where the tubes pass through the connector, each tube has several small holes drilled into its sides. As the water descends from the upper bottle into the lower bottle through one tube, air from the lower bottle is simultaneously pushed up into the upper bottle through the second tube (an effect similar to a percolating coffee pot). As a result of the rapidly moving air in the second tube and the water pressure outside this tube, small amounts of water pass through the holes in the tube and enter the rising airflow. The air and small quantity of water now continue to rise rapidly up the tube and leave the open end of the tube to produce an (intermittent) spurting fountain effect inside the upper bottle.

Predicative challenge

Simple demonstrations that lift anticipation levels by having the student predict the outcome in advance, help promote active engagement in the learning process.

Entrainment bag challenge

Many simple yet surprising experiments on fluid flow can be performed (see, for example, Stewart and Dirks, 2006). The principle of *entrainment* whereby an unconfined moving fluid draws into itself surrounding fluid from its sides is often erroneously attributed to the Bernoulli effect. The important point here is that the Bernoulli effect deals with changes in speed and pressure along streamlines of a fluid flowing in a confined enclosure rather than in a large open space where differences in pressure are quickly able to equalise.

One way to demonstrate the principle of entrainment that requires a little lateral thinking on the part of the student uses a long, cylindrical plastic bag. Using a cylindrical plastic bag whose diameter is about 15 centimetres and whose length is close to 2 metres, tie one end off with a knot and challenge students to blow the bag up using a single breath. Instinctively, most students will take the open end of the bag, and by holding it up against their cheeks, start to blow. Unsurprisingly, such a method at best will only fill about a quarter of the bag with air. Given the length of the tube, the volume of air required to fill it is simply not possible from the air expelled from one's lungs in a single breath. The small amount of air blown into the bag this way should be shown to the class by clasp one hand over the open mouth of the bag and collecting it at the other end by quickly running your clasped hand down the length of the bag. The solution to completely filling the bag using a single breath lies in where one positions one's mouth in relation to the opening. By holding the bag open and blowing directly into it from a distance of about 30 centimetres away, the bag easily fills with the help of entrainment. Here some of the fast moving airstream from one's mouth gets caught up with the surrounding air resulting in additional air being drawn into the bag from the sides of the moving air column. The additional volume of air drawn into the bag

arising from entrainment as a result of blowing some distance back readily fills it using a single breath. See Taylor (2001).

Poles apart

Consider two identical poles, for example long wooden broom handles, which pivot about their end in contact with the ground. When simultaneously released both poles hit the ground at the same instant. Now place a heavy, point-like mass at the end of one of the poles but not the other and ask which pole does one now expect to hit the ground first. Most students will incorrectly predict the pole with the additional mass will hit first as it is heavier; a hangover of the common misconception related to free fall. Both the poles, however, when dropped are not in free fall but are instead rotating about a common pivot point and it is the pole with the greatest angular acceleration which hits the ground first. While the mass of the pole with the additional end mass has increased, its moment of inertia has also greatly increased since this additional mass is also a long way away from the axis of rotation. Since both poles are long, the size of the initial angular acceleration for the pole with the additional end mass will be considerably less than the end-mass-free pole and accordingly hits the ground after the end-mass-free pole does.

Rising bubble

The physics that describes the rise of a bubble through a fluid that is contained within a thin tube, as a function of the angle of inclination of the tube, is far from simple and the result is almost certainly counter-intuitive for most observers. It is abundantly clear that if a tube lies horizontally so that the angle of inclination is zero ($\theta = 0^\circ$) and a large bubble is positioned at one end of the tube, then the bubble will remain stationary unless the tube is disturbed in some way. We can say that the time of travel of the bubble along the tube is effectively infinite and so the bubble will have zero speed. Conversely, if the bubble is positioned at one end of the tube and then the end of the tube opposite to the bubble is quickly raised so that the tube becomes vertical, it is clear that the bubble will travel up the tube in a certain finite time. Immediately after one end of the tube has been raised, the bubble is initially accelerated since the net force is non-zero, but after a relatively short time the bubble attains a constant terminal upward speed (v) through the viscous fluid. Without recourse to a detailed theoretical study of fluid dynamics a 'gedanken experiment' (one performed in the mind and based on our expectation of behaviour), would probably lead us along the following path if we thought about the experiment 'The vertical terminal speed of a bubble rising through a viscous fluid as a function of the angle of tube inclination'. Firstly, when $\theta = 0$ then $v = 0$. Secondly, when $\theta = 90^\circ$ then $v = \text{maximum speed}$. Thirdly, when $0 < \theta < 90^\circ$ then $v < \text{maximum speed}$.

The above thought experiment turns out to be at variance with the correct result, which is obtained experimentally (and confirmed by detailed theoretical analysis) to be as follows: (i) when $\theta = 0$ then $v = 0$, (ii) when $\theta = 45^\circ$ then $v = \text{maximum speed}$, (iii) when $0 < \theta < 45^\circ$ then $v < \text{maximum speed}$, and (iv) when $45 < \theta < 90^\circ$ then $v < \text{maximum speed}$. The reason for these results depends on several physical properties associated with the fluid (viscosity, surface tension), the tube (inclination angle, fluid contact angle, internal diameter) and the bubble (total volume, radius of nose, boundary dimensions) plus other parameters that are required for the complete theoretical analy-

sis. For a detailed theoretical analysis behind the demonstration described here see Lee and Vanden-Broeck (1998) while the case of using tubes whose cross-sectional area are no longer circular is discussed by Bico and Quéré (2002).

Paper folding

How many times can a sheet of paper be folded and does the number of folds depend on the size of the sheet to begin with? The answer to the second of these questions is that the initial size of the sheet of paper used has no impact on the number of folds that can be made (try it using A4 and A3 size sheets to start with). Instead, it is the thickness of the paper used which limits the number of possible folds one can make. Wood pulp derived paper cannot be folded more than about seven or eight times. Every time a fold is made a crease is being formed over twice the thickness of the stack before you made the fold. Thus the first fold creates a crease in which the outer surface has to be doubled back over the initial sheet and thereby forms a layer twice its previous thickness. The next fold results in an increase in thickness by four times, and so on. So no matter what the size of the original sheet of paper, it does not take one long before they must fold a piece of paper whose thickness is between 128 to 256 times its original thickness. At such a point the fibres along the outer fold surface of the paper can no longer support the strain induced from folding over increasingly thicker layers and causes the paper to eventually rupture along the fold line. Thicknesses of 128 ($=2^7$) to 256 ($=2^8$) times the original corresponds to seven or eight folds!

Platform scale magic

A set of simple, striking, yet thought-provoking demonstrations that challenge students initial conceptions about forces and torque involve a pair of platform scales, a supporting board and several weights.

Two platform scales, a supporting board and a single weight – The lever principle

In demonstrating the properties of levers, a light staging board is supported at either end by a pair of platform scales. Start by zeroing the scales. Place a single weight at a number of positions on the board and note the reading on either scale. Students are often amazed to see that the readings on each scale are only equal when the weight is positioned exactly in the middle of the staging board. By placing the weight at a number of positions along the length of the board it should be readily possible to verify that the readings on the scales are inversely proportional to the distance from its end (the lever principle which is related to torque) and that the sum of both readings, in newtons, is always equal to the weight sitting on the board (the equilibrium of forces principle). See Mainardi (2001).

Two platform scales and a single weight – Newton's third law

A particularly striking demonstration of Newton's third law again involves a pair of platform scales and a free weight. In the first instance the scales, both in the upright position, are arranged so that one sits on top of the other with the weight placed on the pan of the top scale. The reading on either scale are noted and it will be observed that the reading on the bottom scale reads the combined weight of the scale above it together with the free weight while the reading on the top scale reads the weight of the free weight only. If instead the top platform scale is inverted so that the pans of the two

scales now touch one another, on placing the free weight on the top of this arrangement each scale will read the combined weight of one scale plus the free weight, a surprising result to most students but not completely unexpected since according to Newton's third law the size of the action and reaction force pairs must be equal. Mainardi (2001) provided the inspiration behind this striking demonstration.

Centre of mass – Balancing

Place several heavy weights randomly along the length of the staging board which in turn is supported at either end by a pair of platform scales. In general the reading on each scale will be different. A student is then asked to move the pair of scales beneath the supporting board until they are next to each other. Typically the student will slowly but carefully move the scales, ensuring as they go not to tip or knock off any of the weights sitting on top of the supporting board, until both scales are finally positioned next to one another. At such a point the scales come together under (or at least very close to) the centre of mass for the system. At this position the reading on either scale will be identical. The intrepid demonstrator repeats the exercise with the exception that this time the two scales are moved very quickly. Once more the scales automatically meet at the same position as previously without any of the weights tipping or falling off the supporting board since the centre of mass for the system, which remains unchanged, is that position where all the weight of the system can be balanced. This demonstration, first seen described by Jones (1987), in its more familiar guise is just the well-known sliding ruler and finger friction demonstration (see, for example, Stewart and Dirks, 2006).

Intriguing surprises

The following five demonstrations are sure to pique more than a passing interest from students and colleagues alike.

Newton's gravity glass

To the casual observer, this appears to be a visual contradiction. As the glass sand timer rises up inside a glass cylinder filled with a viscous fluid at constant speed, the sand continues to descend from the upper chamber to the lower one. This apparent paradox is easily explained. The hollow hourglass shaped sand-filled timer moves upwards through the viscous fluid (confined within a hollow cylinder) due to the buoyant force acting on the body as a whole. As the fluid flows downwards, the glass body behaves like a rigid walled bubble and the nett force on the glass body is zero as soon as constant velocity is obtained, irrespective of any mass re-distribution that is occurring within the glass body. As far as the sand is concerned, the nett force is always going to be downwards (except when the whole apparatus is descending in free fall), so the sand will continue to flow down from the upper chamber to the lower chamber irrespective of the upward motion of the glass container. Does the steady stream of sand descending onto the base of the lower chamber give rise to a nett average force downwards, due to the change of momentum of the stream of sand grains?

The circling keyring

Attach a light mass, say a keyring, to one end of a metre-long piece of string and a heavier mass, say a bunch of keys, to the other end. Pass the string over a pencil such

that the end containing the heavier mass hangs vertically while the lighter keyring end is held out horizontally. On release, the system exhibits a most surprising behaviour. Initially one expects the system to behave like an Atwood's machine where the heavy end descends while the light end ascends since a greater mass is connected to one end compared to the other. At the lighter end, the keyring initially starts to swing like a pendulum, as expected, while the heavier end descends vertically. However, as the heavier end descends, the string attached to the keyring is drawn up closer to the pencil which causes its rotational speed to increase as its radial distance from the pencil decreases. As this end continues to shorten, its angular speed continues to increase to the point where it can complete a full revolution in the vertical plane. This causes the string to wind itself a number of times around the pencil. As the frictional force between the pencil and the string is typically large, the vertically descending bunch of keys stops and is prevented from hitting the ground; a most amazing and unexpected sight. See Ehrlich (1997, 4.11, pp. 74–75).

The tippe top

The tippe top has long been a source of fascination to both causal observer and eminent physicist alike.⁴ In its classical form, it consists of a hemispherical dome which is attached to a short, centrally located stem. If spun on a sufficiently rough surface it will spin on its smooth dome for a short period of time before popping up and continuing to spin on its stem. During this gravity defying inversion, the top not only manages to raise its centre of mass, but changes its direction of rotation relative to itself (relative to you the observer, its direction of spin remains unchanged). Currently, there is no simple explanation for the surprising inversion of the top. It is thought that a sliding frictional force develops on the dome when spinning which creates a torque about the centre of mass and causes the top to invert.

A very simple tippe top can be constructed from a large paper clip (Ucke and Schlichting, 2005). By bending a single paper clip into the shape of a circle so that its ends meet by forming a smaller inner circular loop, if the top is held steady with the inner loop closest to the ground, on being flicked its inversion behaviour becomes apparent since the inner loop of the top will be seen to be spinning high above ground level after it has been spinning for a short period of time. For further discussion on this intriguing object, see Walker (1985).

Square wheels and catenary roads

It is not often one finds any of our students questioning how circular wheels roll over a flat surface. Is this not blindingly obvious? It is generally true however that the simplest of things often turn out to be the most profound. A circular wheel is able to roll smoothly over a flat surface since its centre of mass maintains both a fixed vertical distance above the horizontal and always remains directly above the wheel's point of contact on the road surface. To the total surprise and amazement of most students (and many adults!) it is also possible for many different types of non-circular wheels to roll smoothly and freely over a surface which is no longer flat! Here the classic example is that of a square wheel rolling over a series of bumps in the shape of inverted catenar-

⁴For a photograph showing the two famous physicists Neils Bohr and Wolfgang Pauli hunched over an inverted tippe top, see the *Emilio Segrè Visual Archives* which is available online at <http://photos.aip.org>

ies.⁵ Here the catenary bumps of the surface over which the square wheel rolls ensures that not only does the centre of mass of the wheel remain at all times a fixed vertical height above the horizontal, but this point is also always directly over the point of contact the wheel makes with the road. In fact, it is possible for many different wheels of certain non-circular shapes and sizes to smoothly roll over the same catenary surface. The smallest is a polygon with two curved sides, the next a curved triangle, then square, curved pentagon, and so on. For a set of wheel and road patterns see either Regester (1998) or de Campos Valadares (2006). For a simplified, make-your-own construction that uses square wheels over a bumpy surface which is not quite catenary, see Rathjen, Doherty and the Exploratorium Teacher Institute (2002). Finally, for a detailed mathematical description of the problem which shows, among other things, that the wheel's centre of mass decelerates as the square climbs the catenary and accelerates as it rolls down the other side, see Klein (1993) and Takacs (1994).

Hanging glass trick

Take a small glass and fill it to its brim with water which is free from any visible air bubbles. Next place the filled glass firmly against the underside of a glass plate. Ensure no air bubbles are trapped. Carefully release the glass and observe the unexpected. The glass should be seen to hang freely from the underside of the glass plate. Here the strong force of attraction between unlike substances such as glass and water, known as *adhesion*, causes the water filled glass to stick to the glass plate. As a final note of caution, one should be ready to catch the glass just in case it 'decides' not to stick to the plate.

Weightlessness

The effects of apparent weightlessness are best demonstrated by dropping a body or system of bodies freely under gravity. In the next two demonstrations this is exactly what is done; a variety of things are dropped, or thrown vertically upwards, and the resulting apparent effects of weightlessness observed.

Free falling padlocks under tension

Attach two small padlocks to either end of an elastic band. Hang each padlock over either side of the rim of a stiff, transparent container (the top, cut-away section of a detergent container for example) such that the stretched elastic band is attached to the bottom of the container (a cork with a small hook screwed into it which is then inserted into the opening of the container works best). With this arrangement held at rest, the weight force from each of the padlocks counter-balances the tension of the elastic band. Drop the system and ask what one expects to happen. Both padlocks immediately jump back into the container. In free fall, in the container's frame of reference, the padlocks become weightless and lead to the tension force in the stretched elastic band, which is now unopposed, pulling either padlock over the rim and into the container. This particular demonstration is a small scale version of a similar demonstration we called the 'spring block drop' (see, Stewart and Dirks, 2006, p. 198).

⁵Recall that the *catenary* is the shape a uniform chain or rope takes when it is supported at either of its ends but otherwise hangs freely. Mathematically the shape is described by a hyperbolic cosine function.

Free falling bottle of water under hydrostatic pressure

In a well-known version of a demonstration showing weightlessness, jets of water streaming from a small hole to the side of a water-filled container stop once dropped (Gibbs, 2002, pp. 26–28). Take a tall, narrow, transparent plastic drinking bottle and drill one or two very small holes in its sides close to its bottom. Fill with water and when at rest streams of water flow out of each hole. Here water flows out of each hole since the weight of the column of water above the hole, i.e. the water's hydrostatic pressure, causes the pressure just inside the hole to be greater than the atmospheric pressure just outside the hole and the water accordingly flows from a region of high to low pressure. On dropping, in free fall the water in the bottle's frame of reference becomes weightless and accordingly is unable to exert any hydrostatic pressure. The pressure everywhere within the water drops to normal atmospheric pressure and since there is no longer a difference in pressure across the hole, the streaming jets of water cease to flow. In a lesser known version of this demonstration the bottle is launched upwards instead of being dropped (Corona, Sliško and Planinšič, 2006). Before doing so students should be asked what they expect to happen. Will the jets of water stream out faster, at the same rate, slower, or stop compared to when the bottle was dropped? Reconciling that upward motion also has a free fall component, the water is once more weightless and immediately stops flowing out of the bottle once it is launched upwards. Many other simple experiments demonstrating weightlessness have been described by Kruglak (1987).

Stirling engines

The Stirling engine, named after its inventor Robert Stirling, is a class of heat engine that operates on a closed cycle system in such a way that the air (or other working gas such as helium) is used repeatedly, rather than just once before being exhausted to the atmosphere. The first patent for a new type of 'air engine' was granted to Robert Stirling in 1816, although single-cycle hot air engines were made as early as 1807 based on a somewhat different heating system. Stirling's patent covered the invention of what was initially termed an 'economiser' or 'regenerator' which acts to displace the heated air from the hot side of the engine to the cold side and back again. In a Stirling engine, one side of the engine is continuously heated (by burning fuel externally for example) while the other side is continuously cooled. Initially, the air is moved to the hot side where it is heated and expands, pushing up on the power piston. The air is then moved by the 'displacer' (which usually takes the form of a piston of large surface area that is linked to the power piston with a suitable crankshaft) through the 'regenerator' where it stores some of its heat for the next cycle, to the cold side where it cools and contracts, pulling down on the power piston. The temperature changes that occur inside the engine give rise to the pressure changes required to push up the power piston and enable the engine to perform useful work. Stirling engines are quiet and efficient and come in many shapes, designs and powers, ranging from 75 kW units that are used to provide auxiliary power for submarines, to a small model that will run from the heat of a hand (there is even a tiny model that will work off the heat from a single finger or thumb). The interested reader is referred to Darlington and Strong (2005) where many different types of experimental Stirling engines are discussed.

Conclusion

Teachers of physics are a fortunate lot. The inherent nature of what we teach is readily, and often surprisingly, revealed through the marvellous teaching tool which is the simple demonstration experiment. Often simple demonstrations are the only way one has to help turn the abstract or unfamiliar into something a little more tangible and concrete for those we teach. Simple demonstration experiments also help students explore their own ideas and conceptions about common everyday phenomena, and can be effective in helping them to clarify or correct incorrectly held notions about the physical world before they become entrenched and harder to shed. From our current and earlier work, we have attempted to show that there is indeed no paucity of simple demonstration experiments available to teachers who wish to use them in their teaching. Moreover, the versatility gained through simplicity allows them to be readily performed in settings and circumstances far removed from the ideal. Finally, when used correctly demonstration experiments allow the teacher to harness a powerful epistemic tool that not only has the ability to be both dramatic and entertaining but can also assist in generating active student engagement in the teaching and learning process.

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Engineering

Introducing mechanical engineering to students in the Gulf region

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Abstract

The design and implementation of introductory courses to engineering has been well documented in Western education, in the context of how engineering education practices must adapt to meet the needs of the twenty-first century. As Gulf students exhibit characteristic strengths and weaknesses, engineering education in the region face additional, specific challenges that are associated with economical, social and cultural factors. This paper discusses the adaptation in the Gulf region of Western models of introducing engineering to entry-level students, and describes the strategy adopted at The Petroleum Institute to introduce mechanical engineering to second-year students. Significant blocks of time are devoted to broadening the students' understanding of the mechanical engineering discipline and profession, fields, tools and practices. The traditional aspects of mechanical engineering are concisely covered, enabling emphasis to be placed on the petroleum industry and the broader energy sectors, as well as modern and emerging applications of mechanical engineering. The course structure and teaching methodology focus on developing key professional attributes as identified by ABET,¹ promote student active involvement, and utilise student strengths while tackling characteristic weaknesses in Gulf regional students. After three semesters of offering and evolving of the course, it was found that motivated students could demonstrate excellent proficiencies in what constitutes mechanical engineering in the twenty first-century.

Introduction

It is generally accepted that prior to entering an engineering programme, most students do not possess a basic understanding of the engineering process and profession (Elata and Garaway, 2002; Nesbit, Hummel, Piergiovanni and Schaffer, 2005). This is more evident in engineering than in medicine or law, as everyday life generally offers more opportunities to interact with such professions than engineers. Thus, when secondary school pupils opt for engineering studies, this decision is based upon a perceived natural affinity towards the field (Elata and Garaway, 2002), yet incomplete information (Nesbit, Hummel, Piergiovanni and Schaffer, 2005).

¹ Accreditation Board for Engineering and Technology in the US.

Focusing on second-year mechanical engineering (ME) students, the present authors have observed that student perceptions of the profession and discipline can be significantly outdated. This can be explained in part by the pace of technological advances in the past few decades, which has left society 'behind' in terms of its understanding of the modern profession, and awareness of its applications. Although the underlying principles of ME are essentially unchanged, the field of applications has expanded considerably (Bar-Cohen, 2005). Based on discussions with students and colleagues, the popular perception of ME today appears to be essentially captured from pre-1980s activities, symbolised by large-scale machinery and engines, and key products such as cars and aeroplanes. Applications that fall outside popular visibility remain unknown to the non-specialist. For example, the authors found that most of their second-year ME students were unaware of the involvement of mechanical engineers in biomedical engineering, or of the existence of microelectromechanical structure (MEMS) sensors in cars, though commercialised in the previous decade, or in consumer electronics popular among the younger generation.

The traditional approach to addressing this knowledge deficit has been to incorporate a review of the curriculum and the different branches of ME, as well as of the engineering process, in an introductory first-year course² (Larochelle, Engblom and Gutierrez, 2003). Typically, the teaching approach employed has been based upon traditional, in-class taught lectures. This introduction could eventually be complemented by more advanced *special topics* lectures on ME technologies at third- or fourth-level. However, recent trends in US engineering education are characterised by an inversion (Jones and Oberst, 2001) and improved continuity of the curriculum with respect to design activities (Welch, 2007), which are now incorporated from first-year onwards, rather than waiting until the final-year, and by teaching methodologies that encourage student active participation (Kimbell and Perry, 2001). Examples of introductory engineering courses in line with this strategy are discussed in Hyman (2001), Elata and Garaway (2002), Larochelle, Engblom and Gutierrez (2003), and Nesbit, Hummel, Piergiovanni and Schaffer, 2005; Bullen and Knight (2006). There is evidence that earlier design experiences can also improve first-year retention rates in the US (Bullen and Knight, 2006), the decrease of which has been partly attributed to the traditional focus on mathematics and physics in first year (Elata and Garaway 2002). In this approach, an overview of ME technical subject areas and applications can be covered in the engineering science courses (e.g., thermofluids, mechanics and materials, automation and control), rather than in a traditional, dedicated introductory course (Larochelle, Engblom and Gutierrez, 2003).

Jones and Oberst (2001) note that the US engineering educational model is attractive to many countries both for its qualities and the fact that it is an important contributor to the success of the technology driven economy in the US. They also note a shift of engineering education in Europe closer to the US model, with the *Bologna Declaration*. In the Gulf region, third-level education strives to produce educated nationals of equal standing to the West, and is seeking regional and international recognition

²Such an introductory first-year course can also extend to topics including computer literacy (e.g., word processing, spreadsheet software), engineering statistics (e.g., data processing), engineering graphics, computer programming, machine shop laboratories, engineering measurement laboratories, communication, or engineering ethics.

through ABET accreditation (ABET, 2007). However, cultural, linguistic, economical, social, and political factors, can constrain the level to which Western education models can be implemented in the region (Jones and Oberst, 2001).

Such factors add further dimension to understanding and practicing modern engineering for entry-level United Arab Emirates (UAE) students. As the local population does not have a long tradition of occupations in engineering, opportunities to interact with engineers can be more limited than elsewhere. Indigenous professionals are outnumbered by expatriates, who do not necessarily speak Arabic. Furthermore, UAEs industry is strongly focused on key sectors, namely oil and gas, information technology (IT), civil and infrastructure manufacturing (Randeree, 2006), with the result that the work force does not have direct exposure to the full diversity of possible engineering career paths. Despite the opportunities that the local oil and gas sector will continue to offer for decades to come, it is important for the UAE's government and education system to prepare tomorrow's engineers to the development of other industries (e.g., alternative energy sources), which have the potential to further contribute to the region's wealth in the twenty-first century and beyond. Technology news on sources including *Newsweek*, *Time Magazine*, *New Scientist*, *Scientific American*, and ASME³ mechanical engineering magazine offer valuable insight into modern ME applications, in a style and format intended for the non-specialist. However, the fact that such information can only be accessed in a foreign language is an additional barrier to knowledge dissemination, although English is the primary language used in the third-level engineering education. Other challenges faced by the Gulf's engineering education efforts include cultural, moral and learning issues (Ohadi, 2006; Randeree, 2006). Gulf students exhibit characteristic strengths and weaknesses. The former include natural affinities for team-work and good oral presentation skills, while weaknesses can be found in reading large portions of authentic text, writing, expecting to be passive recipients of taught information and lacking independence in the approach to problem solving (Randeree, 2006). Lecturers of natural science courses can struggle to complete course syllabi in the same amount of time as allocated in Western universities, and feel that more time is required to cover key fundamental concepts, with no or insufficient time left to cover engineering technologies and applications, either in project assignments or dedicated lectures. Difficulties have been reported to meet the goals of modern engineering education within a four-year curriculum, with major blocks of time devoted to build the background of students in areas not typical in Western engineering education (Jones and Oberst, 2001). Finally, retention issues are also encountered, which are attributable to the lack of financial incentives to work, and which can lead young Nationals to opt out of professions that require high levels of preparation and dedication (Jones and Oberst, 2006). The above circumstances invite local universities to carefully consider adaptation of Western education models.

Established in 2001, the mission of The Petroleum Institute (PI) is to educate the local work force in fields of engineering (Chemical, Electrical, Mechanical, Petroleum and Petroleum Geosciences) that will serve the on-going needs of the oil and gas industry in the Gulf region. The Institute, whose goal is to become a leading third-level academic institution in the Gulf, has been working in cooperation with affiliate universities in the US and Europe, to tailor Western education models to the needs of local

³American Society of Mechanical Engineers.

industry. The five engineering curricula are taught in English, with the Foundation English Program of the Institute being the first programme outside the US to be accredited by the CEA⁴ in 2006.

It is in the above context and in line with ABET outcomes that the two credit hour second-year course presented in this paper, Introduction to Modern Mechanical Engineering (MEEG205), was developed. It was felt that such a two-credit, discipline-specific course focusing on the modern and local ME profession and discipline, contributing to develop attributes necessary for professional development (Laity, Aung, Benson, Bernard, Fisher, Gourley, King, Menon, Nott, Perry, Simoneau, Stong, Warrington and Wepfer, 2004; NACE,⁵ 2006; ABET, 2007) – including qualities expected in a design engineer (Welch, 2007) – would be a better solution to meet the programme educational goals, in conjunction with the rest of PI ME curriculum, than attempting to cover ME applications in fundamentals of engineering courses, as proposed by Laroche, Engblom and Gutierrez, (2003) in the US. Mainstream ME fields and practices are concisely covered, enabling emphasis to be placed on the petroleum industry and the broader energy sectors, as well as modern and emerging applications of ME. This strategy takes into consideration the employment sector of the PI students (oil and gas industry), UAEs long-term plans to develop alternative energy sources, and addresses the students' outdated perception of ME. The professional attributes targeted in MEEG205 consist of team, communication, ethical reasoning, and societal and global contextual analysis skills, as well as motivation/initiative, curiosity and work strategies. The development of these attributes is addressed by the course topical contents, structure and teaching methodology.

MEEG205 is carefully articulated with the remainder of the ME curriculum. To help students make a more informed decision when selecting a major that will correspond to their skills and aspirations, MEEG205 is preceded by a one-credit, *Engineering Success Seminar* (ENGR103), which provides an overview of the engineering specialisations taught at the Institute. The integration of design-and-build activities at an early stage in the PI ME curriculum is achieved through so-called 'pre-final-year' design experiences (see, e.g., Elata and Garaway, 2002; Laroche, Engblom and Gutierrez, 2003; Nesbit, Hummel, Piergiovanni and Schaffer, 2005), as part of a six-credit programme titled Strategies for Team-based Engineering Problem Solving (STEPS210 and STEPS251). In this programme, the students integrate their knowledge in science, mathematics, and communications, with team work and project management tools, to solve open-ended engineering design problems, including the design and construction of useful machines (Scott and Ahmad, 2007). Professional attributes are also developed in the following common engineering courses, undertaken by all PI students. During ENGR103 students learn study skills and time management. Two four credit hour communication modules (COMM101 and COMM151) prepare first-year students to following a full curriculum in English, and provide them with a working knowledge of multi-media communication tools. During the STEPS design experiences, the students also practice a range of professional skills. Collectively therefore, a significant number of credits, relative to Western educational practices, are devoted to building study skills and professional qualities. Although beyond the scope of this paper, the PI is currently

⁴Commission on English Language Program Accreditation in the US.

⁵US National Association of Colleges and Employers.

driving an innovative secondary school project, which aims at an improved continuity (Welch, 2007) and articulation of engineering education at the secondary-level (Jones and Oberst, 2001).

To the authors' knowledge, the present introduction to mechanical engineering (MEEG205) is unique in the Gulf region. Although three other universities in the region also offer engineering introductory courses, these are discipline non-specific. The main objectives of MEEG205 are:

- To raise entry-level students' understanding of the modern ME profession and discipline.
- To reinforce student motivation and curiosity to pursue their ME professional and educational goals.
- To prepare the students to the ME curriculum and the real life engineering practice in the local and global working environment.
- To familiarise the student with engineering tools.
- To develop professional attributes, including team, communication, and ethical reasoning skills, awareness of the economic, societal and global context for engineering solutions, to increase awareness of the importance of life-long learning, to engage in self- and peer-evaluation, to exercise initiative, curiosity, and to practice work strategies.

The course outcomes and their relationship to ABET criteria for accrediting engineering programmes (ABET, 2007), denoted in brackets, are as follows:

- Demonstrate a general understanding of the modern ME discipline and profession, in terms of their evolution, curriculum, relationship to other disciplines, career paths, application areas including the oil and gas industry, contemporary issues and future directions (h, j).
- Demonstrate an awareness of the global, economic, environmental and societal context of an engineering problem (h).
- Demonstrate an ability to use techniques, skills, and engineering tools necessary for modern engineering practice (k).
- Demonstrate competency in sourcing, evaluating and analysing information related to a engineering topic (i, g, k).
- Demonstrate competency in oral and written communication, in a simulated engineering related context (g).
- Demonstrate effective team work in a simulated engineering context (d).
- Demonstrate awareness of professional and ethical responsibility (f).
- Demonstrate an ability to acquire new knowledge independently (i).

Course topics, structure and format

The topics, structure and format of MEEG205 were designed to address the above outcomes, in tandem with the rest of the PI ME curriculum. The course commences with an historical perspective of ME, reviews the ME curriculum and introduces applications of the fundamentals to different areas, with emphasis on the oil and gas industry. The course progresses on to the use of engineering tools, focusing on codes and standards, computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), and sources of scientific information. Once the students are familiar with traditional fields of ME, significant blocks of time are devoted to exploring the directions of ME in the twenty-first century: biotechnology, micro/nanotechnology, energy/ecology, and information technology (Laity, Aung, Benson, Bernard, Fisher, Gourley, King, Menon, Nott, Perry, Simoneau, Stong, Warrington and Wepfer, 2004).

The course is implemented in one semester over nineteen weeks with a two hour meeting each week. The format of the lectures is oriented towards interactive learning, where the students become active participants and constructors of their own knowledge, rather than passive recipients of taught information (Kimbell and Perry, 2001; Randeree, 2006). The lecturer's notes and short presentations are essentially used as a support to catalyse student participation, and to subsequently refine or correct student understanding of a particular topic. Many opportunities are given to the students to engage in oral and written communication, team work, independent learning and critical thinking, characteristics that should be particularly emphasised in young Gulf archetypal students (Randeree, 2006). This is achieved through team-based activities involving sourcing, evaluation and analysis of technical information, and leads to in-class debates, discussions, and presentations varying from informal or spontaneous (e.g., commenting information) to formal and well-prepared (using a data projector). These activities involve the use of technical publications, technology and business news, educational videos, Internet-based animations, invited lectures by industry experts and alumni sharing their job experiences, and a field trip. Overall, therefore, the course format utilises the students' natural oral communication skills to enhance effective learning, while also tackling potential weaknesses in written communication, and passive and dependent learning practices that were possibly inherited from pre-tertiary education. The course is structured as follows:

- Three in-class activities involving informal presentations, discussions or tutorials on topics such as history of ME, links between the ME curriculum and ME applications areas, ME career paths, analysis of codes and standards, professional ethics.
- Three formal student presentations accompanied by in-class discussions on topics such as expert predictions of peak/plenty of oil availability scenarios, gas processing, renewable energy sources, a typical CAE analysis process and application, and the analysis of a major public-domain ethical case in engineering.
- Eight application-area specific lecturer presentations or invited lectures accompanied by class debates and discussions (e.g., ME design process, thermofluid applications in the oil and gas industry, product reliability, mechatronics, hybrid

vehicles, prospects for a hydrogen economy, fuel cells, micro/nanotechnology, bioengineering).

- One educational video (e.g., ME in the electronics industry) accompanied by in-class discussion.
- One computer-based library literacy laboratory.
- One meeting with alumni sharing their job experiences.
- One field-trip to local industry.
- Short tests, homework, mid-term and final examination.

For conciseness purposes, only a snapshot of the course activities outlined above are presented in this paper and are given to illustrate the topical content of the course and teaching methodology used. This sample is limited to the following portions of the course:

- Historical perspective of ME.
- Computer-based library laboratory on searching and evaluating scientific information.
- Student presentation and in-class debate on predicted oil scenarios.
- Field trip to a major gas processing plant in the UAE.
- Invited lecture on fuel cells and prospects for a hydrogen oriented economy.
- Engineering ethics, including the analysis of a public-domain case.

Historical perspective of ME

In this activity, the class works in teams to build a historical perspective of mechanical systems and the ME discipline. The objective is for the students to gain an appreciation of past contributions of ME and technology to society, and how mechanical systems have evolved. This perspective gives the students an overview of the contribution they could make by being creative, and thus a sense of how they can influence the future. Historical aspects can constitute a new concept to certain students, as history is not systematically included in primary and secondary level education in the UAE. In this regard, the PI curriculum also includes two three-credit social science electives, titled *The UAE Before and Since Oil* (H&SS222) and *The West in the Middle East* (H&SS201).

Before the class, the students work in teams to identify mechanical systems designed at different periods, spanning antiquity, the Middle Ages and Renaissance, industrial revolution, early and late twentieth century, and twenty-first century. Examples of systems spanning these periods are illustrated in Figures 1 to 4. The students justify their system selection and identify the mechanical engineering effort that would be involved today in the design of such machines. Each team presents their findings during the class. The students evaluate each others findings and presentations by completing a questionnaire and making constructive comments orally. The evaluation includes

identifying key elements of technological progress in each mechanical system. For example, the machines shown in Figures 1 to 4 illustrate the evolution of power generation, from man- and animal-powered, to water-, steam-, and electricity-driven machines. The modernism of both the Roman communal room heating system (Figure 1d) and the Korean Ondol (Figure 1e) resides in the concept of heat integration/utilisation, which is a major research area in ME today. The degree of complexity and miniaturisation of the Antikythera Mechanism (Figure 1f), a geared astronomical calculator, is also remarkable. The students' attention is drawn to the expansion of ME applications, most of it was limited to military, civil and agricultural uses prior to the industrial revolution, to a number of application areas in the twentieth century. The evolution of computer technology (Figure 3a) illustrates the transition from purely mechanical to electro-mechanical systems, as well as progress in miniaturisation and functionality. The twentieth century's electro-mechanical systems are then contrasted with emerging bio-mechanical or bio-electro-mechanical systems of the twenty-first century, pointing to future directions in ME. The examples in Figures 1 to 4 highlight increased cross discipline interaction, which culminates with biomechatronics (Figure 4b).

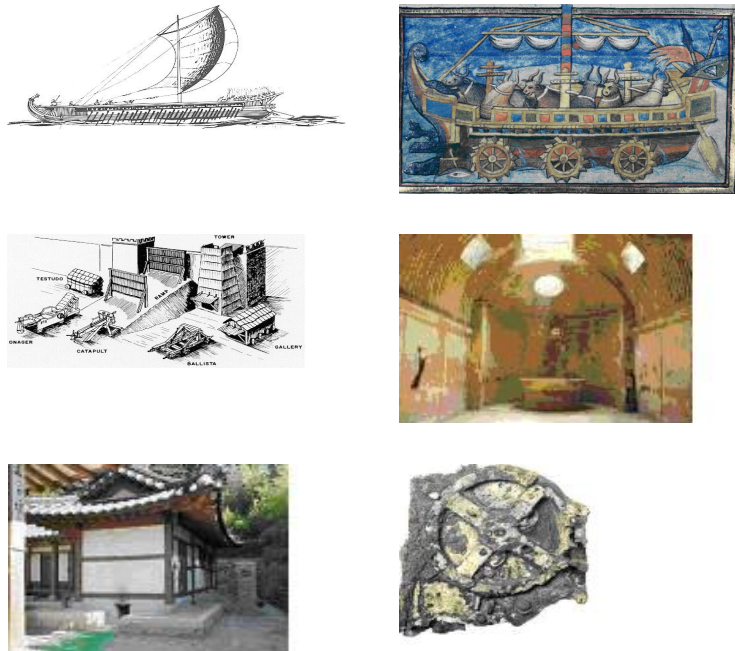


Figure 1: Antique machines. (a) Top left: Man-powered boat. (b) Top right: De Rebus Bellicis, an ox-powered boat (ca. 4^{ACE}). (c) Middle left: Greek, Macedonian and Roman military machines. (d) Middle right: Roman changing room with a finned-wall cavity heating system (200^{BCE}–79^{ACE}). (e) Bottom left: The Korean Ondol (37^{BCE}–668^{ACE}), a building heating system. (f) Bottom right: The Antikythera Mechanism (ca. 100^{BCE}), a geared astronomical calculator.

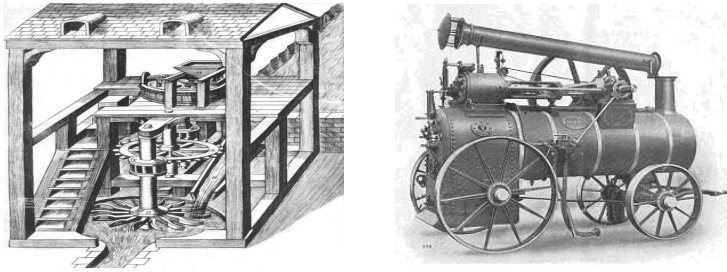


Figure 2: Examples of water and stream-driven machines. (a) Left: Water-driven grain mill (ca. 1600s). (b) Right: Steam-driven tractor (ca. 1800s).

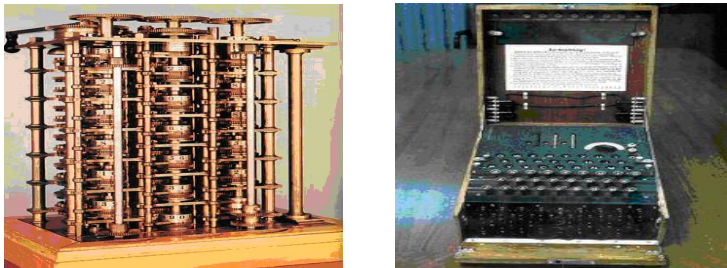


Figure 3: Machines illustrating the transition from mechanical (left) to electro-mechanical (right) systems. (a) Left: Babbage's differential mechanical computer (1820s). (b) Right: The Enigma (1920's onwards), a portable battery-powered cipher machine to electrically encrypt and decrypt secret messages. The mechanical parts form a varying electrical circuit.

To sketch the evolution of the ME discipline, in terms of the subjects taught, the students are invited to name scientists who contributed to ME fundamentals. As many students in the class have attended or are attending in parallel statics, dynamics, and thermodynamics courses, they are familiar with scientists from the seventeenth to nineteenth centuries who were principally responsible for developing mechanics (e.g., Newton, Hamilton, Lagrange) and thermodynamics (e.g., Boyle, Kelvin). The need for universities to develop ME as a separate field in the early nineteenth century, to provide manufacturing machines and the engines to power them, is highlighted. Based on this discussion, the evolution of the discipline is depicted from its classical origins, mechanics and thermodynamics (Laity, Aung, Benson, Bernard, Fisher, Gourley, King, Menon, Nott, Perry, Simoneau, Stong, Warrington and Wepfer, 2004) to a contemporary curriculum. To conclude, the students are invited to interpret and comment on ASME's educational council's vision of the discipline, as evolving from 'the branch of engineering that encompasses the generation and application of heat and mechanical power and the production, design and use of machines and tools', to 'one that addresses societal concerns through analysis, design, and manufacture of systems, at



Figure 4: Mechatronics and biomechatronics applications. (a) Left: Mars rover (2004), illustrating mechatronics. (b) Right: Pill camera (2001 onwards). The latest mechatronics prototypes contain a lens, a video chip and lamp, a microactuator, a power and data antenna, and a microfluidics-based lab-on-chip.

all size scales.’ (Laity, Aung, Benson, Bernard, Fisher, Gourley, King, Menon, Nott, Perry, Simoneau, Stong, Warrington and Wepfer, 2007).

Current technologies and applications areas in ME

In this section of the course, the students gain an insight into various fields within ME, with emphasis on the petroleum industry. An initial two hour session is devoted to discuss the engineering profession, a review of the PI ME curriculum, and applications of the fundamentals to practical engineering activities is highlighted. Rather than the lecturer supplying the information, the class is divided in ‘reflexion groups’ which summarise their combined knowledge of a particular topic by completing a detailed questionnaire. Examples of reflexion topics include contrasting engineering and science, identifying engineering skills, describing the main engineering fields, illustrating concurrent engineering, contrasting mechanical engineering specialisations (e.g., mechanical versus petroleum engineering), career paths and working environments, identifying mechanical engineering products and activities in a given industry sector, comparing the tools available to the twenty-first century engineer versus those available a few decades ago, identifying growing application areas in mechanical engineering, and the role of ASME and scope of its activities. Each group presents their thoughts to the rest of the class, and a global discussion is engaged to refine the results. In this activity, the lecturer tends to act as a moderator, the objectives being to encourage student active involvement through a lively discussion and independent learning, to develop student confidence to present their views to their peers, to make constructive comments on their peers’ work and conversely, to accept and benefit from criticism. The lecturer circulates and monitors the teams, and provides hints and feedback. Application areas of ME are discussed in more detail in subsequent lectures. Two topical activities are presented below: the petroleum industry, and ME in electronics.

ME applications related to the petroleum industry

To provide the student with an economical, societal and technological context associated with the planet’s energy challenges, a two-weeks of course work is organised on

the peak oil / plenty of oil debate (Eveloy, Rodgers, Al Hashimi, Ohadi and Gupta, 2006). In teams, the students source information on oil scenarios using the Institute's library facilities, Internet, databases of scientific information, and when required, by seeking clarification from academics at the Petroleum Engineering and Petroleum Geosciences Programs. A library literacy laboratory (see later) is held under the supervision of a librarian and the lecturer, during which the students learn to use databases such as INSPEC and COMPENDEX and other sources to document their project topic. In a subsequent lecture, each team presents its literature review and personal interpretation to the class, by highlighting in more detail a particular oil scenario or expert's perspective. This activity sensitises the students to the context of their future employment sector – the local oil and gas industry – and highlights the contribution that they could make to help resolve the planet's energy challenges. This topic also prepares the students to a subsequent session on alternative energy sources.

Most students were found to be very receptive to the peak oil/plenty of oil controversy, which they closely relate to, and became emotional when sharing their views. The lecturer helped the student to refine their interpretations and moderated their views, for example when these tended to be one-sided or based on matters of personal preference rather than scientific and balanced arguments.

Following on from this introductory activity to the energy industry, subsequent lectures are organised on thermofluid applications in the oil and gas industry (e.g., heat exchangers use in various oil and gas processing steps) and product reliability (e.g., reliability challenges in plants, pipelines, and oil and gas electronics, reliability assessment methodologies). In addition, a meeting is organised with members of alumni employed in the local oil and gas industry, who share their job experiences with the class.

ME and electronics

Electronics is an important topic for entry-level ME students, who must understand that the integration of electronics with mechanical systems is a major backbone of the twentieth century's ME achievements (ASME, 2007). This highlights the need for interdisciplinary and cross-disciplinary skills. There are two facets in introducing the interaction between electronics and ME to the students. Firstly, the role of electronics in today's mechanical systems, and secondly but conversely, the mechanical engineering effort involved in designing, manufacturing and sustaining electrical and electronic systems.

Regarding the first facet, students are confronted with the fact that the performance and functionality of today's machines has been in large part enabled by electronics and progress in miniaturisation. The lecturer presents industry trends on semiconductor device miniaturisation (e.g., Moore's law) and the evolution of computing capability. An educational video provides additional insight to the semiconductor industry, and semiconductor manufacturing and encapsulation processes. As an illustrative example, the principles of photolithography, a key enabling technology for transistor scaling, are summarised. During a field trip to local industry, the students appreciate how electronics have enabled an increased level of automation in oil and gas recovery equipment.

Many MEs employed in the local oil and gas fields specialise in failure analysis of oil and gas production and transportation equipment. A substantial portion of such failures can be caused by the electronics (Tiku, Venerusol, Etchells and Pecht, 2005).

Therefore, is important to stress to ME students that in designing and maintaining a mechanical system, basic cross-disciplinary skills in electronics may be required. A meeting was organised with a PI ME graduate who shared his job experiences of failure analyses of rotary equipment used in local gas plants with the class. Also, a UAE researcher gave an invited lecture on his PhD research in the area of mechatronics, undertaken at a leading Japanese university.

Regarding the second facet, MEs are needed in the electronic industry, from designing, manufacturing and maintaining electronic hardware, from package level to cabinet, and facility level. Most reliability analyses of electronic equipment and electronics cooling activities are undertaken by MEs. The students are familiarised with electronic cooling hardware such as fans and heat sinks. This part of the course is illustrated using practical case studies from industry, drawn from the lecturers' industrial experience (Rodgers, Eveloy and Pecht, 2005).

The topic of electronics naturally leads to micro- and nanotechnology. For example, the relationship between device miniaturisation, computing capability and mechanical sensing and actuation capability is highlighted by presenting microelectromechanical structures (MEMS).

Emerging technologies in ME

Once the student are familiar with mainstream ME fields and career paths, emerging directions of ME in the twenty-first century are introduced. These directions are identified as the four O's in ASME's educational council vision on how engineering education needs to adapt to address the needs of twenty-first century's society and technology: Micro/Nano Technology, Information Technology, Ecology/Energy and Biotechnology (Laity, Aung, Benson, Bernard, Fisher, Gourley, King, Menon, Nott, Perry, Simoneau, Stong, Warrington and Wepfer, 2004). As illustrative examples, the Ecology/Energy and Micro/Nano Technology themes are summarised below.

Ecology/Energy

Forming the 'energy engineer of 2030' is a long-term educational goal in the Gulf region (Ohadi, 2006). In MEEG205, the ecology/energy theme is addressed through project work, an invited lecture, and supporting information provided by the lecturer. As a starting point, a sample of ME contributions to the energy and environment sectors are reviewed. These include drilling techniques and equipment for improved oil recovery, energy-efficient cars, power plants, heat exchangers and HVAC⁶ systems, and the development of renewable energy sources.

In project work, the students research alternative energy sources, including solar, wind, biomass, and nuclear energy, and summarise their potential advantages over hydrocarbon fuels. The students present their results in class and are invited to consider the potential and feasibility of implementing such alternative energies in their country. The lecturer uses Internet-based visualisations to clarify basic principles of fuel cell operation. The students search examples of fuel cell applications (e.g., power plants, portable electronics, fuel cell powered vehicles) from technology news such as the July 2006 issue of *Mechanical Engineering* (Hutchinson, 2006; Winters, 2006a), which

⁶Heating, ventilation, and air conditioning.

describes ‘the car of the future’, in which internal gasoline combustion engines are used in tandem or replaced with gas engines, hydrogen combustion engines or electric-powered engines. From their reading activity, the students are prompted to identify and summarise the concepts of hybrid cars and fuel cell powered vehicles.

A recorded conference presentation by an international expert, Professor Peter Edwards from Oxford University (Edwards, 2006), is also given on the prospects of a hydrogen-oriented economy and fuel cells as a way to utilise hydrogen as a fuel. Topics such as hydrogen production and storage, and carbon sequestration are introduced in this lecture. The lecturer interrupts the presentation every few overheads and prompts the students to answer key questions to verify their understanding. The lecturer highlights the professionalism required for conference presentations, draws attention to the structure and format of the presentation, sources of information employed, and other characteristics of the lecture as a model.

Other energy-related topics introduced in the course include microbial enhanced oil recovery (MEOR) and environmental engineering, as part of a separate session on bioengineering.

Micro/Nanotechnology

ME has evolved as a discipline capable of analysing, designing, and manufacturing components and systems at all size scales (Laity, Aung, Benson, Bernard, Fisher, Gourley, King, Menon, Nott, Perry, Simoneau, Stong, Warrington and Wepfer, 2004), prompting the need for multi-scale engineering education (Lin, 2001; Karami and Pieri, 2007). Electronics and electronic packaging are a good example to illustrate the scaling of engineering applications, and students were introduced to Moore’s law and its impact on computing capability in an earlier lecture. As a follow-up from this lecture, an introduction to MEMS and their fabrication is given. MEMS are an extension of integrated circuits that contain micro-scale sensors and actuators, such as gears and pistons, features that were only designed on the macro-scale in the past. After the lecture, the students are invited to find additional MEMS applications (e.g., automotive airbag accelerometers, digital micro-arrays), identify the functionalities of the sensing and actuating parts, and highlight the multi-physics nature of the MEMS operation when applicable.

From micro-scale, the course progresses to nano-scale. The students are introduced to the concepts, challenges of nanotechnology, its potential applications and perceived risks. Their attention is drawn to the September 2006 issue of *Mechanical Engineering* (Winters, 2006b), which highlights, for example, carbon nanotubes (CNTs) and fullerenes, two types of engineered nanostructures which are now finding a multitude of applications in things such as composite materials due to their outstanding mechanical properties. Other application areas covered include biomedical sensors, diagnostic and treatment devices including futuristic nano-robots and nano-scale particles for targeted drug delivery to treat cancers in a localised manner. The students are invited to consider the foreseeable advent of nano- and molecular computers.

Engineering tools and practices

Three categories of engineering tools are emphasized in the course: codes and standards, CAD/CAE/CAM, and sources of scientific information.

The students are prompted to reflect on the need for and origins of codes and standards. From the industrial revolution onwards, products were manufactured using machinery, requiring modularity so that parts manufactured in different factories could be assembled together. The formation of ASME was partly motivated by the need for standards for the design of pressure vessels, which in the 1880s failed catastrophically due to a combination of poor design, manufacturing, and use conditions. The use of codes and standards is highlighted for various equipment, including consumer products. The students complete assignments to familiarise themselves with the various standard bodies (e.g., ASTM, BSI, IEEE, ISO), and the type of technical definitions and guidelines used by designers, manufacturers, and operators in industry in order to comply with a given standard.

From the authors' observations, many students have a poor appreciation of the need to source technical information (e.g., perform a literature review) in the conceptual phase of a design activity, such as a senior design course. In addition, entry-level students possess basic Internet search skills, but generally have difficulties to evaluate the credibility, relevance and usefulness of technical information. As previously mentioned, the information literacy skills of young students in the Gulf region can be impaired by the difficulty of understanding large sections of authentic text (Randeree, 2006). In addition, entry-level students are unaware of databases of scientific publications such as INSPEC and COMPENDEX. To address these weaknesses, a computer-based laboratory is held at the library, where the students learn to use such databases and other sources to document a contemporary engineering topic such as oil production scenarios. This laboratory is scheduled at the beginning of the semester so that students can practice the use of databases in other assignments in the current course and throughout the remainder of their curriculum. Students practice having to quickly scan the fields of a publication (e.g., title, abstract, conclusions, section titles, graphics, author affiliation) and to assess its relevance, usefulness and credibility. At the completion of the laboratory, the students hand out the list of technical publications that they have sourced, and that they will subsequently use in project work (e.g., the peak oil/plenty of oil project). All students are invited to critically compare the characteristics and contents of information they have sourced from the Internet, scientific databases, and textbooks.

Various computer tools and their applications are introduced: programming (e.g., Matlab), equation solvers (e.g., Mathematica), and sophisticated CAE programs used in industry (e.g., computational fluid dynamics, stress analysis software). The lecturer explains how engineers use theoretical analysis to estimate behaviour, and CAE to make predictions and create designs. This is illustrated using a typical CAE simulation process for an analysis typical of ME. Of particular importance is understanding the limits of engineering theory and CAE model in predicting actual system performance. Both the capabilities and potential limitations of CAE are highlighted. Experimental and virtual prototyping are contrasted, and how they complement each other. Practical case studies are presented to illustrate the use of CAD/CAE/CAM, such as the design of a car, simulation of its performance (e.g., car aerodynamics and engine stress analysis) and car manufacturing. Students complete an assignment to find and compare characteristics of commercially-available CAE tools (e.g., in terms of their modelling capabilities, and application areas) based on on-line product literature, and to sum-

marise an example application of such tools to a given ME design or analysis activity.

Engineering ethics

The purpose and contents of professional codes of conducts, including the ASME code of ethics, are explained and illustrated through a tutorial and the analysis of a major public-domain case (e.g., the Challenger and Columbia space shuttles disasters, the Ford Pinto gas tank, the Exxon Valdez oil spill). After analysing the case, the students present their findings to the rest of the class. The tutorial focuses on ethical situations representative of a corporate environment (e.g., issues arising in dealings with colleagues, customers, and third parties) and is based on material from the NCEES⁷ *Fundamentals of Engineering* examination.

Field trip

A one-day field trip to local industry is organised each semester, such as to an oil drilling company or gas processing plant. Such trips provide opportunities to the students to observe the working environment, familiarise themselves with ME specialisations and the various aspects related to the plant operation, through discussions with working engineers. An assignment is associated with the field trip, such as giving a presentation on a typical natural gas processing step, related equipment, and the role of mechanical engineers. Such trips are generally very well received by the students, who find their visit extremely informative in terms of the working environment of a UAE mechanical engineer in the oil and gas industry.

Concluding remarks

For most students, MEEG205 represents their first exposure to current and emerging technologies and applications in mechanical engineering. Mature and curious students reacted positively to this new information. However, during the first course offering, many students were initially sceptical of the usefulness of various topics, which were not fundamentals-oriented. The fact that the majority of the course did not involve calculations, but acquiring a general understanding of mechanical engineering concepts, appeared to be disorienting. Some confused certain course topics with social sciences rather than engineering. Because the course was two credit hours, certain students had the perception that it should not involve significant work relative to a normal three credit hour subject.

Students also had difficulties identifying how much they should learn and what they should deliver to obtain good marks on assignments. They realised that the knowledge of a professional engineer in a particular field of ME, could vary from novice to specialist level, and that they had latitude to decide how much they wanted to learn. The fact that a particular area of ME did not seem to have well-defined boundaries, unlike topics in other fundamental courses which progress chapter by chapter, also appeared to be confusing. To ease these issues, the students were provided with a set of self-assessment questions for each topical area. In addition, homework and short tests were

⁷National Council of Examiners for Engineering and Surveying.

assigned that focused on answering key questions related to the course material. Students were also puzzled by the existence of overlap between ME and other engineering fields, and appeared to be reluctant to 'make space' to learn from other disciplines. For example, they initially questioned the need for a session on electronics in mechanical systems, forcing the lecturers to provide detailed justifications as to why such areas were important.

Most students did not take sufficient notes during the class. Few students appeared to read technology news, despite the availability of technology-oriented magazines, and the Internet. Therefore, the lecturers frequently forwarded technology and business news articles from, for example, the BBC website and ASME's mechanical engineering magazine, to the class.

When working in teams, students were overly co-operative in terms of helping other teams. The lecturers gave different assignments to the teams when possible, and incorporated originality in the marking scheme.

Such observations are consistent with previously reported learning issues in the Gulf region (Randeree, 2006). Nevertheless, the lecturers have observed a continued improvement in student responsiveness to the course over a three-semester period. This is attributed to addressing learning needs and issues observed in the previous semester, in terms of course content and delivery methodologies. This effort will be pursued in forthcoming semesters to further refine course learning outcomes.

Finally, the role of women is identified as one of four areas in the Arab world where 'change is taking place,' and where engineering educators could succeed (Jones and Oberst, 2006). Whereas in the US, for example, only thirteen per cent of ME students are females (Wolcott, 2007), the enrollment statistics of women in engineering in certain Arab countries are extremely encouraging (Jones and Oberst, 2006). However, female ME career paths are likely to differ from male ones due to cultural factors. Therefore, an introductory engineering course such as the present one may require additional tailoring for female students, the first of whom will join the PI ME Program in Spring 2008.

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Preparing engineering students for environmental stewardship in the twenty-first century: The Petroleum Institute design teams develop plastics recycling plan

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Abstract

The STEPS II Course (Strategies for Team-Based Engineering Problem-Solving) at The Petroleum Institute in Abu Dhabi introduces second-year student design teams to authentic engineering problem solving in the twenty-first century, with special emphasis on environmental and humanitarian issues facing engineers in both our local and broader global communities. The responsibilities of professional global engineers is stressed, including stewardship of our planet and its resources; the health, safety, and welfare of its inhabitants; engineering ethics, and intercultural communication. Student teams are mentored through an ‘experience’ of engineering design methodology that incorporates creativity and inventiveness, technical thinking, decision-making, communications skills, and graphical demonstration. The STEPS II project for the autumn semester of 2006 involved the development of a plastics recycling plan for The Petroleum Institute, with applications locally and globally. The project exposed students to the concept of reusable energy resources, the societal impact of recycling, environmental issues in engineering design, data collection and analysis, manufacturing processes, safety, modelling techniques, graphics communication as well as economic considerations. At the beginning of the course our students were uneducated about the seriousness of the plastics waste problem, relatively unaware of what was happening at The Petroleum Institute and in their community with regard to recycling, and doubtful that their personal efforts could produce an innovative and effective solution to a serious global dilemma. They had limited vision with regard to researching the topic, and were perplexed by the open-ended nature of the project. Throughout the semester the students gained confidence in their abilities as global citizens and engineers to help solve global problems facing their generation and future generations. They gradually learnt how to think ‘outside the box’ about possible solutions, and were excited about the possibility of real implementation of their ideas in the real world. The students ‘footwork’ and visibility on campus and in the community at large was an important first step in building public awareness. Details of the experience the students went through in this project and their interactions with the community and The Petroleum Institute administration are presented and discussed in this paper.

Introduction

The autumn 2006 semester of the STEPS (Strategies for Team-Based Engineering Problem-Solving) II Course at The Petroleum Institute (PI) in Abu Dhabi was an experiment in second-year engineering design curriculum. The course introduced second-year student design teams to authentic engineering problem solving in the twenty-first century, with special emphasis on environmental and humanitarian issues facing engineers in both our local and broader global communities. The responsibilities of professional global engineers was stressed, including stewardship of our planet and its resources; the health, safety, and welfare of its inhabitants; engineering ethics, and intercultural communication. Student teams were mentored through an 'experience' of engineering design methodology that incorporated creativity and inventiveness, technical thinking, decision-making, communications skills, and graphical demonstration. The autumn 2006 semester STEPS II project involved the development of a plastics recycling plan for the PI, with applications locally and globally. The project exposed students to the concept of reusable energy resources, the societal impact of recycling, environmental issues in engineering design, data collection and analysis, manufacturing processes, safety, modelling techniques, graphics communication, as well as economic considerations.

At the beginning of the course our students were uneducated about the seriousness of the plastics waste problem, relatively unaware of what was happening at the PI and in their community with regard to recycling, and doubtful that their personal efforts could produce an innovative and effective solution to a serious global dilemma. They had limited vision with regard to researching the topic, and were perplexed by the open-ended nature of the project. Throughout the semester the students gained confidence in their abilities as global citizens and engineers to help solve global problems facing their generation and future generations. They gradually learned how to think 'outside the box' about possible solutions, and were excited about the possibility of real implementation of their ideas in the real world. The students 'footwork' and visibility on campus and in the community at large was an important first step in building public awareness. Details of the experience the students went through in this project and their interactions with the community and the PI administration are discussed in this paper.

The Petroleum Institute's STEPS programme: The challenge of translating Western models into effective curricula in the Arab world

The STEPS programme is designed to introduce engineering students at The Petroleum Institute to the theoretical and intellectual concepts as well as the practical methods used in engineering design in an integrated two semester sequence at a very early stage in their engineering education. The STEPS programme is unique to the United Arab Emirates (UAE), and is the first of its kind in the Gulf region. Teaching students the concepts and practices required to successfully tackle an open-ended engineering design problem is one of the more challenging jobs for any engineering educator but is especially challenging when the students belong to a culture vastly different from their Western counterparts in origin, experience, and custom. This paper describes the process of establishing a new curriculum for the STEPS programme designed to address

our students' needs to develop and exercise open-ended problem-solving skills, develop environmental sensitivity in engineering design, perform research that supports their decision-making, and work in interdisciplinary teams to tackle authentic problems in their local and global careers.

With funding from a consortium of major oil companies including The Abu Dhabi National Oil Company, Shell, BP, Total and JODCO, and led by a team from the Colorado School of Mines (CSM), the PI was established in 2001. The goals of the institute include educating UAE nationals in fields of engineering (Chemical, Electrical, Mechanical, Petroleum and Petroleum Geosciences) that will serve the on-going needs of the oil and gas industry in the Gulf region. Experienced design academics from the CSM were brought to the PI in the autumn of 2003 to foster and implement a programme modelled after the CSM EPICS (Engineering Practices Introductory Course Sequence) programme.

As expected, many of the paradigms and expectations consistent with Western engineering design programmes simply do not yield the same outcomes in the Arab culture. Our students have exhibited different strengths and weaknesses from their Western counterparts. For instance, our students' teamwork is enhanced by their heritage in the etiquette of Arab friendship, and oral presentations are strong and natural as a result of an oral cultural orientation. On the other hand, writing skills are naturally impeded by the fact that English is their second language. The design-and-build nature of the projects is often hindered by a lack of familiarity with tools and construction techniques. And so on. The authors are constantly adapting and modifying the course content and delivery methodologies in order to provide appropriate learning outcomes for our students.

Rationale for the development of a new model in STEPS II

Need to develop independent, open-ended, problem-solving skills

As part of a two-semester sequence, STEPS I presents students with a well-defined design-and-build problem, and then leads them through the process using the concepts of guided design. The students are also given extensive instruction in the application of soft skills that are important to successful design, namely teamwork, project planning, and professional oral and written communications. Academic advisers from engineering and communications programmes serve the role as mentors for this project. During the first three years of the programme's development, the STEPS II semester was characterised by a similar format to STEPS I, but with discipline specific design-and-build projects. After three years the programme's new Coordinator, Jamal Ahmad, and Co-mentor, Suzanne Scott, looked for ways to improve STEPS II.

By the autumn of 2006, the authors had identified some problem areas in our curriculum. The supposedly sequential two semesters were looking too much alike. Although our students were confronted with more technically challenging discipline specific projects in the second semester, they were still not thinking creatively about problem solutions. They had difficulty applying their scientific and mathematical skills to their project problems. Their research and data collection efforts rarely extended beyond the Internet. Students had difficulty seeing their ideas and project solutions as having any impact or affect on anyone beyond their team and the semester. Although

by the end of STEPS I most of the students were willing to concede that engineering problems often have many possible solutions, in STEPS II they still needed a great deal of guidance thinking ‘outside the box’. They wanted the mentors to supply them with ‘the right answers’. Kasim Randeree, a former lecturer in the College of Engineering at UAE University identified these characteristics ‘Students in the UAE exhibit certain characteristics emerging from a variety of cultural and historical traditions, as well as from methodologies of education used at the pre-tertiary levels. These characteristics include expecting to be passive recipients of taught information and lack of independence in their approach to problem solving’ (Randeree, 2006).

We realised that we needed to come up with a model that helped our students develop their open-ended, problem-solving skills. In STEPS I, the projects thus far had included design models, such as solar miniature race cars, Rube Goldberg machines, and an egg relocation device. The students expected STEPS II to follow the same somewhat formulaic design sequence within the same parameters. We decided that we needed to give the students a sense of more authentic, less-defined engineering problems. We needed a theme that would connect their thinking with their authentic community, not just with their team mates in the classroom.

Need to teach environmental sensitivity in engineering design

Abu Dhabi and the larger UAE have experienced rapid growth in the past three decades. This oil-rich nation has experienced unprecedented economic and social development, especially in the urban areas of Abu Dhabi and Dubai. Along with rapid modernisation, urban development, and five per cent per year population increases, the cause for sustainable development and waste management has recently become vocalised in a few agencies and concerned groups. One agency taking up the cause of sustainable development, the Emirates Environmental Group (EEG), is a non-government group located in Dubai that encourages education for sustainable development, waste management, conservation, renewable energy production, and other issues, by targeting stakeholders such as the UAE government, businesses, communities and civil society groups (Al Marashi, 2006). While the EEG has spearheaded community projects in recycling, and has mounted awareness campaigns in the Dubai area, we were aware of little activity in our Abu Dhabi community.

We wondered what our students knew about sustainability. What were their perceptions about their responsibilities as engineers in the twenty-first century? Did they care? What is being done to foster awareness in this part of the world? Should environmental sustainability and global stewardship be at the core of our engineering design programme? We wondered if focusing the STEPS II semester on environmental projects would serve several objectives. While giving the students authentic, challenging, open-ended problems through environmental projects we would also be exposing and educating our students to topics such as reusable energy resources, the societal impact of recycling, environmental issues in engineering design, sustainable design, humanitarian design.

Connecting with the PI community and beyond

We then brainstormed the possibilities for improvement in different design skills. Would the students’ research skills and data collection skills improve because of the authenticity and ‘concern’ related to the issue? Could a model similar to Purdue Univer-

sity's EPICS (Engineering Practices in Community Service) programme serve our programme? At Purdue, students operate in a service-learning context to fulfill the complementary needs of engineering undergraduates and the community. Purdue identifies the educational need for undergraduates as 'facing a future in which they will need more than just a solid technical background to be successful...expected to interact effectively with people...work with people from many different disciplines' and the community need as 'community service agencies, schools, local governments...face a future in which they must rely to a great extent upon technology for the delivery, coordination and improvement of the services they provide to the community. They thus need the help of people with strong technical backgrounds' (Jones and Oberst, 2006). Does the idea of doing something creative to help solve serious problems affecting the students and future generations serve to motivate students in problem solving? Would caring and concern be engendered? How would an environmental theme support skills in graphics, professional interaction, and economics analysis?

Preparing our students for global careers

Downey, Lucena, Moskal, Bigley, Hays, Jesiek, Kelly, Miller, Ruff, Leer and Nichols-Belo (2006), have identified the need to prepare our students for global careers. We felt that the environmental emphasis would give us an opportunity to introduce the topics of global stewardship, environmental ethics, engineering codes and the environment, the possibilities of working on international teams, intercultural communication and international problem solving.

Fuchs and Mihelcic (2006) have identified the need for reform in engineering education in the Arab world and all parts of the world, 'as universities prepare graduates to enter the profession of engineering which has been transformed by massive technological developments and by globalisation of all aspects of concern to engineers. Engineering educators in the Arab states region face particular challenges in addition to those facing similar educators in other parts of the world (including) tailoring programs to fill the needs of countries that are undergoing rapid modernisation'.

Existing models teaching sustainability in and across engineering curricula

We found several Western models upon which to draw ideas for the new course emphasis. One of them, Michigan Tech's *Sustainable Futures* model, is intended to 'foster education and research on sustainability for society, the environment, and economic/industrial development...so that...engineers can manage projects that reach across borders to raise the global standard of living and environmental quality.' These engineers will acquire the capacity 'to work on interdisciplinary projects (and) solve problems while working in foreign cultures' (Carnegie Mellon University, 2006). Surely the future careers of our students will require them to work on interdisciplinary teams.

Turner, Li and Martinez (2001) described their efforts at the University of Texas at El Paso (UTEP) in 'developing sustainable engineering across a college of engineering' and point out that ABET¹ criteria require that all engineering students develop an understanding of the impact of engineering solutions in a global context as well

¹ Accreditation Board for Engineering and Technology, based in the US.

as have knowledge of contemporary issues as they relate to engineering. They state, 'there is evidence that many engineering programs do not perform well in these areas. Sustainable Engineering initiatives can provide an avenue for improving performance'. The College of Engineering at UTEP has developed a programme for the teaching and learning of sustainable engineering concepts in each and every engineering programme.

Probably one of the best-known efforts to incorporate sustainability and green design into engineering is the Carnegie Mellon programme. Carnegie Mellon began a campus-wide Green Design Initiative in 1992 to promote environmentally conscious engineering (Carnegie Mellon University, 2006).

Stanford Engineering's Civil and Environmental Engineering department has organised its teaching and research around the theme of sustainability, with efforts focused on five areas: water, urbanisation, health, the Earth's life support systems, and buildings (Stanford School of Engineering, 2006).

Identifying learning objectives, outcomes, and format

After considering the nature and scope of the potential new model for STEPS II, we ultimately decided on the following statement of our learning objectives:

Through mentored class work, interdisciplinary teamwork, and campus and community interaction in an environmental project students will acquire the knowledge, awareness, and problem-solving skills needed to assimilate sustainable development factors when solving community and global engineering problems.

The following outcomes, along with their relationship to ABET criteria in brackets, are listed below.

At the end of STEPS II students should be able to demonstrate the following:

1. Demonstrate competency in oral and written technical communication (g).
2. Demonstrate understanding of the principles of project management (d).
3. Demonstrate effective teamwork (d).
4. Demonstrate ability to gather, analyse, and interpret data. (b).
5. Apply engineering design process to solve an open-ended project (b,c,e).
6. Apply appropriate engineering practices to solve engineering problems (a,c).
7. Demonstrate competency in graphics applications (k).
8. Demonstrate awareness of professional ethics and codes of conduct (f).
9. Demonstrate awareness of global issues facing contemporary engineers, including environmental sensitivity and intercultural communication (h,j).

A syllabus was created that led the students through the iterative steps in the design process, with special emphasis on authentic interactive experiences (speakers, surveys, and interactive demonstrations). Outcomes were added over the course of the semester to focus the students on various topics associated with the project.

The project: A plastics recycling plan for the PI

The chosen project for the autumn semester of 2006 involved the development of a plastics recycling plan for the PI. The student teams were required to address the issues of collecting, sorting, baling, transporting, cutting, processing, marketing, and selling plastics recyclable waste. The project also emphasized building public awareness and involving all stakeholders in the process of reducing waste. Project requirements included innovation in the development of a plan (including a patent search), data collection and analysis concerning the magnitude of the problem, types of plastics used, the most common types found in the waste stream, and the proportion of these plastics that get recycled. The teams' research had to provide information on previous recycling efforts, governmental and non-governmental agencies involved, and existing recycling systems put in place. A feasibility study was required, along with a study of societal and environmental impact. Ultimately the teams were to discuss the feasibility of scaling up the plan for Abu Dhabi and the UAE.

Students' expectations versus reality of solving real engineering problems

Our students were initially bewildered by the scope of the project and had difficulty brainstorming and envisioning problem solutions. They expected the course to follow the same formula as STEPS I, i.e., guided design with design-and-build models. 'Show us the right answer and we'll build it.' 'Isn't this what engineers did?', were typical responses. This was their comfort zone. How could an environmental project be considered engineering? The project felt too ambiguous. The students resisted and procrastinated on assignments that stretched their thinking. We realised that this sort of problem-solving was new to them.

In *Definition of the engineering method*, Koen (1985) states that '(a) primary goal of collegiate education is to help students mature into skilled and responsible open-ended problem solvers. . . .[C]omplex real world problem solving requires a wealth of skills including technical competence, teamwork, self-education, creativity, and evaluation of alternatives. These all feed into the most important ability, being able to make reasoned decisions in an ambiguous situation and taking responsibility for the consequences.' We realised we had to push our students to experience and develop more complex thinking and evaluating skills. This was a struggle, but the experiential nature of the project helped to foster these skills in a natural progression. At other times we had to focus and direct their attention to a task at hand and demand its completion. Our students progressed (albeit uncomfortably) from the expectation of a previous paradigm with a single right answer to the seeming acknowledgement of uncertainties and unknowns in the project that required them to think differently.

Development of the awareness campaign

Very early in the semester the authors posed to the students the question of how to

create awareness of the plastics waste problem on our campus and in our community. The students were quick to come up with a number of options, which were in turn asked of their survey participants. The idea of an 'awareness campaign' was formed, based on survey results that indicated that the respondents would be more receptive to an ongoing campaign, rather than sit and listen to lectures on the subject. The students' plans consisted of activities leading up to a 'plastics recycling awareness day' which was held near the end of the semester. Brochures were created and posters were displayed to advertise the upcoming event. The students videotaped 'mini-commercials' to attract attention to the plastics waste problem and to demonstrate possible solutions at the PI. On 'plastics recycling awareness day' the students set up their displays and activities in a highly trafficked lobby on campus. Their mini-commercials, as well as a video of 'Plastics Man' demonstrating correct disposal of plastics, caught the attention of students. A popular activity was 'Identify the Plastics,' in which several types of plastics in various forms were displayed and the students were asked to see if they could identify them. But perhaps the most eye-catching exhibit was an enormous bag of plastic cups (approximately four thousand) that the students displayed as the amount of cups consumed at the PI in one day.

The students' plans: Two teams and one solution

Each of two five-member teams produced three conceptual solutions (plans) and applied a decision-making matrix to narrow down the solutions to one plan. The two teams produced solutions that addressed the main functions of a recycling plan, including collecting, sorting, baling and marketing the sorted plastic waste. The two teams' conceptual solutions emphasized specific functions over others. The Newland Team, for example, realised the importance of public participation in making the recycling plan successful, so they made building public awareness a key function in their plan. The other team, PIPRS (Petroleum Institute Plastics Recycling System) focused on reducing plastic waste by reusing it. They introduced an additional initial function of sorting the plastic waste according to its reusable condition. After selecting a concept solution, the teams further developed the selected concept into a detailed solution. This included breaking down the plan into subsystems and specifying the tasks, milestones and outcomes in each subsystem. Toward the end of the semester, the two teams produced detailed plans that had considerable overlap. The authors and the General Services Department at the institute then advised the students to combine their efforts into one detailed plan. The two teams discussed the merger and agreed to combine efforts. In the process of combining the plans decisions had to be made on which subsystems of each plan should be eliminated. The final recycling plan that emerged was very similar to that of the Newland Team and consisted of these subsystems: public awareness; collecting; sorting; baling; and marketing. In addition, a detailed economic feasibility analysis was completed for the plan.

Results of student-administered PI-wide survey

From the beginning the students appropriately identified their PI peers and PI academics as the most important stakeholders in the recycling effort. It was necessary to assess the stakeholder's awareness of the plastic waste problem at the PI and their willingness to take an active role in any recycling effort. For this purpose, the students developed and administered a survey. The survey was administered to one hundred stu-

dents and fifty academics and staff (roughly ten per cent of the student and three per cent of the academic and staff population). After the survey, the students developed and conducted the awareness campaign, described in this article. Results from the survey were used to tailor the awareness campaign to the public need. For example, the survey indicated that the majority of the participants had no idea of the size of the plastic waste problem at the PI. In the awareness campaign, the students created a visual effect demonstrating the number of plastic cups consumed every day at the PI. After the campaign, the students conducted a follow-up survey in order to assess the impact of the campaign on the public. Figure 1 illustrates some results from the two surveys showing an increase in public awareness.

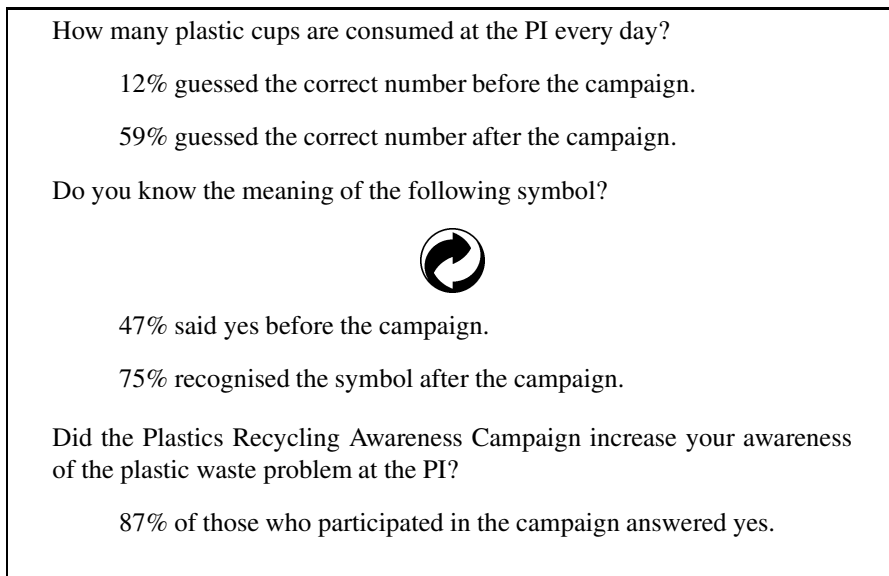


Figure 1: Sample survey results on public awareness for plastic cup usage at The Petroleum Institute (PI).

Evaluation of the autumn 2006 ‘Experiment’: A new curriculum model that promotes environmental sensitivity in the solution of open-ended problems in engineering design

The authors conducted a survey of the students’ awareness of recycling in general and their assessment of the impact of engineering practices on the environment. The first survey was conducted at the beginning of the semester, and a follow-up survey was conducted at the end of the semester. Results from the two surveys indicated that the students became more aware of the importance of engineering in solving societal and environmental problems, of their role as key players in solving existing problems, and of opportunities to improve their communities. Figure 2 illustrates some of these results obtained from the two surveys.

Does Abu Dhabi or the UAE have an environmental agency that addresses recycling?

40% said yes at the beginning, while 100% said yes at the end.

90% of the students could name these agencies at the end of the semester.

How can you identify which plastics are recyclable?

50–70% of the students could identify plastics by their physical and mechanical properties at the end of the semester.

Only 10% could do the same at the beginning.

Does the PI recycle? If so, what does it recycle?

80% thought that the PI had a recycling activity at the beginning of the semester. At the end of the semester 20% still believed that there is a recycling activity at the PI.

Figure 2: Sample results of follow-up survey.

Some other opinions that were not bench-marked at the beginning of the semester may also indicate an increased awareness of the students' (or engineers') responsibility toward the environment. For example, eighty per cent of the students believed that engineers are responsible for protecting the environment, one hundred per cent would consider protecting the environment a priority, and sixty per cent would consider a career in the environment protection sector.

Concluding thoughts

At the beginning of the semester our students were uneducated about the seriousness of the plastics waste problem, relatively unaware of what was happening at the PI and in their community with regard to recycling, and doubtful that their personal efforts could produce an innovative and effective solution to a serious global dilemma. Throughout the semester the students gained confidence in their abilities as global citizens and engineers to help solve problems facing their generation and future generations. The authors watched them progress from timid offerings of ideas and solutions they had found on the Internet to proudly presenting their own creative and appropriate solutions for the PI and their community. We observed their problem-solving skills progress from unenthusiastic and shortsighted attempts to find solutions, to confident and excited research, a positive desire to communicate and disseminate their ideas, and satisfaction in making a difference.

The students are excited about acting as advisers to the student teams in next semester's project, seeing their recycling plan implemented at the PI, and attending a conference to share their experience.

Acknowledgements

Although The Petroleum Institute had few efforts in recycling (paper only) we found that our PI community was not completely without concerned teachers and students with regard to the environment. Our point persons on the two PI campuses were Mr Michael Ford (Women's Campus) and Mr Yahya Al Rayyes, (Men's Campus). We also found the PI's Health, Safety and Environment Committee helpful and supportive in our efforts. Supporters included Dr John Williams and Ms Sireen Salman. Members of the PI's General Services Department, Mr Mahmoud Shehada and Mr Eliot Mengote, supplied needed answers to feasibility and implementation questions of any plan for the campus. We were also aware of an Environmental Club on campus, but that attendance and regularity of meetings was spotty. Lecturers also supplied our students with the names of their contacts in business and industry. Speakers included Dr Barry Posner, an expert on environmental economics, and Dr Sulafudin Vukušić, a lecturer in chemistry, who gave an interactive presentation on identifying types of plastics.

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Java versus C++ for engineering education

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Abstract

At present there are a number of computer programming languages taught in different engineering schools curricula. During the last decade, the programming language for the introductory programming course moved from structured languages such as C to object-oriented programming language such as C++ and Java. The recent change in the College Board Advanced Placement examination in Computer Science to use Java instead of C++ resulted in an increasing number of universities, colleges, and secondary schools adopting Java as their language of choice for introductory programming courses. The language chosen for this examination is based on the language commonly taught in introductory computer programming courses at the university level. This paper reviews both the purpose of the introductory programming course and the suggestions for the course curriculum published by the Association for Computing Machinery. Based on this fundamental curriculum, two programming languages (Java and C++) are considered with recommendations made on the most appropriate language for use in an introductory course. This is done by highlighting the primary differences between using Java and C++. In addition, the strengths and weaknesses of Java and C++ are considered in the context of teaching such a course. It is anticipated that such a study will provide engineering educators with a way to introduce programming from a problem-solving perspective rather than focusing on the programming language itself.

Introduction

The *College Board*¹ is a US organisation for creating and administering common examinations for secondary school students such as the Scholastic Aptitude Test (SAT) and the various Advanced Placement (AP) examinations. In particular, the AP examination enables students to complete their secondary school education and also receive credit for university-level courses at specific academic institutions. Started in 2003, the AP examinations in computer science used Java as the programming language of choice. Between 1998 and 2003, the language for the exam was C++ and prior to that

¹See <http://www.collegeboard.com>

it was Pascal. The AP Program offers two computer science courses: Computer Science A and Computer Science AB (College Board, 2006). The content of Computer Science A is a subset of the content of Computer Science AB. Computer Science A emphasizes object-oriented programming methodology with a concentration on problem solving and algorithm development and is meant to be the equivalent of a first-semester, university-level course in Computer Programming. It also includes the study of data structures, design, and abstraction, but these topics are not covered to the extent that they are in Computer Science AB. Computer Science AB includes all the topics of Computer Science A, as well as a more formal and in-depth study of algorithms, data structures, design, and abstraction. For example, binary trees are studied in Computer Science AB but not in Computer Science A. The AP Computer Science A course is compatible with topics covered in a typical first course in computer science as described in the example curricula listed in the Association for Computer Machinery (ACM) guidelines (ACM, 2004). The additional topics in the AP Computer Science AB course are consistent with a typical second course in computer science in those sample curricula.

Over the last forty years ACM curricula recommendations have played an important role in defining what is taught at educational institutions around the world. The latest ACM report on Computer Engineering Curriculum includes one core course in programming called Programming Fundamentals. The report has some comments on the course and provides the description and the learning outcome for the course as summarised in the next section. The ACM report emphasizes the use of an object-oriented programming language and puts considerable emphasis on problem solving rather than the syntax of the language. The selection of a programming language for introductory courses has long been an informal process involving lecturer evaluation, discussion, and consensus (Parker, Chao, Ottaway and Chang, 2006). As the number of lecturers, students, and language options grows, this process becomes increasingly unwieldy. Parker, Chao, Ottaway and Chang (2006) presented a structured method for selected programming language. However, the authors did not find these criteria very useful.

ACM programming fundamentals

Competency in a programming language is a prerequisite to the study of computer engineering. Undergraduate programmes must teach students how to use at least one programming language. The difficulty of achieving the necessary level of fluency in a programming language is further complicated by the need to include many advanced techniques. Students should cover the core topics in this unit to receive exposure to the basic pieces that should be covered independent of a particular programming language. Object-oriented programming, event-driven applications, and the use of extensive application programming interfaces (AIPs) have become fundamental tools that some computer engineering students need early in their academic programme. These concepts may be included in a programme that only teaches an object-oriented language such as C++ or Java. The course contents and learning outcomes are summarised below for the following topics which can be taught as either core or elective: (i) History and overview (core); (ii) Programming paradigms (core); (iii) Programming constructs (core); (iv) Algorithms and problem-solving (core); (v) Data structures (core); (vi) Re-

cursion (core); (vii) Object-oriented programming (elective); (viii) Event-driven and con-current programming (elective); and (ix) Using application programming interfaces (elective). A detail description of each topic follows.

History and overview [core]

Minimum coverage time: 1 hour

Topics:

- Indicate some reasons for studying programming fundamentals.
- Highlight some people that influenced or contributed to the area of programming fundamentals.
- Indicate some important topic areas such as programming constructs, algorithms, problem solving, data structures, programming paradigms, recursion, object-oriented programming, event-driven programming, and con-current programming.
- Contrast between an algorithm and a data structure.
- Distinguish between a variable, type, expression, and assignment.
- Highlight the role of algorithms in solving problems.
- Describe some of the fundamental data structures such as array, record, stack, and queue.
- Explain the various programming paradigms such as procedural, functional, logic, and object oriented.
- Explain how divide-and-conquer strategies lend themselves to recursion.
- Explore some additional resources associated with programming fundamentals.
- Explain the purpose and role of programming fundamentals in computer engineering.

Learning outcomes:

1. Identify some contributors to programming fundamentals and relate their achievements to the knowledge area.
2. Define the meaning of algorithm and data structure.
3. Know the reasons that a way to solve problems is by using algorithms.
4. Distinguish the difference between a stack and a queue.
5. Identify the difference between various programming paradigms.
6. Explain recursion and the way it works.
7. Describe how computer engineering uses or benefits from programming fundamentals.

Programming paradigms [core]

Minimum coverage time: 5 hours

Topics:

- Procedural programming.
- Functional programming.
- Object-oriented design.
- Encapsulation and information-hiding.
- Separation of behaviour and implementation.
- Classes, subclasses, and inheritance.
- Event-driven programming.

Learning outcomes:

1. Identify the paradigm used by pseudo-code snippets.
2. Identify the appropriate paradigm for a given programming problem.

Programming constructs [core]

Minimum core coverage time: 7 hours

Topics:

- Basic syntax and semantics of a high-level language.
- Variables, types, expressions, and assignment.
- Simple input/output (I/O).
- Conditional and iterative control structures.
- Functions and parameter passing.

Learning outcomes:

1. Analyse and explain the behaviour of simple programs involving the fundamental programming constructs covered by this unit.
2. Write a program that uses each of the following fundamental programming constructs: basic computation, simple I/O, standard conditional and iterative structures, and the definition of procedures and functions.

Algorithms and problem-solving [core]

Minimum coverage time: 8 hours

Topics:

- Problem-solving strategies.
- The role of algorithms in the problem-solving process.
- Implementation strategies for algorithms.
- Debugging strategies.
- The concept and properties of algorithms.
- Structured decomposition.

Learning outcomes:

1. Define the basic properties of an algorithm.
2. Develop algorithms for solving simple problems.
3. Use a suitable programming language to implement, test, and debug algorithms for solving simple problems.
4. Apply the techniques of structured decomposition to break a program into smaller pieces.

Data structures [core]

Minimum coverage time: 13 hours

Topics:

- Primitive types.
- Arrays.
- Records.
- Strings and string processing.
- Data representation in memory.
- Static, stack, and heap allocation.
- Runtime storage management.
- Pointers and references.
- Linked structures.
- Implementation strategies for stacks, queues, and hash tables.
- Implementation strategies for graphs and trees.

- Strategies for choosing the right data structure.

Learning outcomes:

1. Identify data structures useful to represent specific types of information and discuss the trade-offs among the different possibilities.
2. Write programs that use each of the following data structures; arrays, records, strings, linked lists, stacks, queues, and hash tables.
3. Describe the way a computer allocates and represents these data structures in memory.

Recursion [core]

Minimum coverage time: 5 hours

Topics:

- The concept of recursion.
- Recursive mathematical functions.
- Divide-and-conquer strategies.
- Recursive backtracking.
- Implementation of recursion.

Learning outcomes:

1. Explain the concept of recursion.
2. Explain the structure of the divide-and-conquer approach.
3. Write, test, and debug simple recursive functions and procedures.
4. Describe how recursion can be implemented using a stack.

Object-oriented programming [elective]

Topics:

- Polymorphism.
- Class hierarchies.
- Collection classes and iteration protocols.
- Fundamental design patterns.

Learning outcomes:

1. Outline the philosophy of object-oriented design and the concepts of encapsulation, sub-classing, inheritance, and polymorphism.
2. Design, code, test, and debug simple programs in an object-oriented programming language.
3. Select and apply appropriate design patterns in the construction of an object-oriented application.

Event-driven and concurrent programming [elective]

Topics:

- Event-handling methods.
- Event propagation.
- Managing concurrency in event handling.
- Exception handling.

Learning outcomes:

1. Design, code, test, and debug simple event-driven programs that respond to user events.
2. Defend the need for concurrency control and describe at least one method for implementing it.
3. Develop code that responds to exception conditions raised during execution.

Using application programming interfaces (APIs) [elective]

Topics:

- API programming.
- Class browsers and related tools.
- Programming by example.
- Debugging in the API environment.
- Component-based computing.

Learning outcomes:

1. Explain the value of APIs in software development.
2. Design, write, test, and debug programs that use large-scale API packages.

Based on the above course description, the core component of the course requires thirty-nine contact hours. This leaves six hours for the electives topics to make the course three credit hours. Although the course content of the AP course Computer Science A is not show in this paper, there are a lot of similarities between the two courses (College Board, 2006). A successful attempt to map the course topics into a well known textbook in Java (Deitel and Deitel, 2005) is made in a subsequent section.

Java versus C++ for the programming fundamentals

Eckel (2000, 2006) has published two excellent textbooks in object-oriented programming, one written using C++, the other using Java. Older editions of these textbooks are available free for download. Eckel also gives seminars about the advantages of Java over C++ among other seminars in object-oriented programming. However, the content of the textbook *Thinking in Java* by Eckel (2006) does not fit the ACM programming course description. However, the book does provide guidance on the differences between Java and C++. Deitel and Deitel (2004, 2005) have also published two comprehensive textbooks on Java and C++. These textbooks are almost identical, in that they both use the same examples and exercises. The textbooks can therefore be used to provide the reader with a clear idea on the differences between Java and C++. Deitel and Deitel (2005) stated that their Java textbook covers all the material of the Computer Science AP examination as well as the topics of the Sun Certified Java Programmer exam (SCJP). However, Deitel and Deitel's Java textbook has twenty-nine chapters and the book can be used for two semesters to cover some advanced topics in Java. The differences between Java and C++ are intended to be significant improvements, and if one understands the differences, it will become evident why Java is such a beneficial programming language. The following points listed serve to highlight the important features that distinguish Java from C++.

1. Java has both kinds of comments like C++ does. Java supports a third type of comment called Javadoc. The javadoc utility program (part of the J2SE Development Kit) reads Javadoc comments and uses them to prepare your program's documentation in HTML format
2. Everything must be in a class. There are no global functions or global data. If you want the equivalent of global, make static methods and static data within a class. There are no structs or enumerations or unions, only classes.
3. All method definitions are defined in the body of the class. Thus, in C++ it would look like all functions are inline, but they are not.
4. Class definitions are roughly the same form in Java as in C++, but there is no closing semicolon. There are no class declarations, only class definitions.
5. There is no scope resolution operator:: in Java. Java uses the dot for everything, but can get away with it since you can define elements only within a class. Even the method definitions must always occur within a class, so there is no need for scope resolution there either. One place where one will notice the difference is in the calling of static methods.
6. Java, like C++, has eight primitive types for efficient access. All the primitive types have specified sizes that are machine independent for portability. Type-checking and type requirements are much tighter in Java.
7. The char type uses the 16-bit Unicode character set, so it can automatically represent most international characters.

8. Java adds the triple right shift `>>>` to act as logical right shift by inserting zeros at the end.
9. Although they look similar, arrays have a very different structure and behaviour in Java than they do in C++. There is a read-only length member that tells how big the array is, and run-time checking throws an exception if the program gets out of bounds.
10. All objects can be created only via `new`, with the exception of `String` objects. Arrays of primitives are a special case, they can be allocated via initialisations as in C++ or by using `new`.
11. Java has no preprocessor; to use a class in another library the `import` key word is used.
12. Java uses packages in place of name spaces.
13. Object handles defined as class members are automatically initialised to null. Initialisation of primitive class data member is guaranteed in Java.
14. There are no Java pointers in the sense of C++. When an object is created with `new`, a reference (handle) is given back.
15. Java has constructors that are similar to constructors in C++. However, there is no destructor in Java. There is a `finalise ()` method that is a member of each class, something like a C++ destructor, but `finalise ()` is called by the garbage collector.
16. Java has method overloading that work virtually identical to C++ function overloading.
17. There is no `goto` in Java. The unconditional jump mechanism is the `break` label or `continue` label.
18. Java uses a singly-rooted hierarchy, so all objects are ultimately inherited from the root class `Object`.
19. Java has no templates or other implementation of parameterised types. There is a set of collections: `Vector`, `Stack`, and `Hashtable` that hold `Object` references.
20. Garbage collection mean memory leaks are much harder to cause in Java. The garbage collector is a huge improvement over C++, and makes a lot of programming problems simply vanish.
21. Java has built-in multi-threading support. There is a `Thread` class that can be extended to create a new thread.
22. Instead of controlling blocks of declarations like C++ does, the access specifiers (`public`, `private`, and `protected`) are placed on each definitions for each member of a class.

23. Java has inner classes that look just like nested classes. However, an object of an inner class keeps a handle to the object of the outer class that was involved in the creation of the inner class object.
24. No inline methods in Java.
25. Inheritance in Java has the same effects as in C++, but the syntax is different. However, Java does not provide multiple inheritances, at least not in the same sense that C++ does. The interface keyword takes care of combining multiple interfaces.
26. Java provides the interface keyword, which creates the equivalent of an abstract base class filled with abstract methods and with no data members.
27. There is no virtual keyword in Java because all non-static methods always use dynamic binding. In Java, the programmer does not have to decide whether to use dynamic binding.
28. Exception handling in Java is different because there are no destructors. A finally clause can be added to force execution of statements that perform necessary cleanup. All exceptions in Java are inherited from the base class Throwable.
29. Exception specifications in Java are vastly superior to those in C++. Instead of the C++ approach of calling a function at run-time when the wrong exception is thrown, Java exception specifications are checked and enforced at compile time. In addition, overridden methods must conform to the exception specification of the base-class version of the method.
30. Java has method overloading, but no operator overloading. The String class does use the + and += operators to concatenate strings and String expressions use automatic type conversion, but that is a special built-in case.
31. The const issues in C++ are avoided in Java by convention. You pass only handles to objects and local copies are never made automatically. To create a compile-time constant value, the static final keywords are used.
32. Java has built-in support for comment documentation, so the source code file can also contain its own documentation, which is stripped out and reformatted into HTML via a separate program.
33. Java contains standard libraries for solving specific tasks. C++ relies on non-standard third party libraries. These tasks include: Networking; Database Connection; Multi-threading; Distributed Objects, Compression, and Commerce.
34. Java provides a simple and fun entry point into reactive programming via Applets, graphical user interface-based programs that run from HTML pages. Further, because Java directly integrates concurrency constructs into the language itself, larger scale multi-threaded reactive programming techniques can be introduced relatively early and naturally, without needing to switch to other languages or tools.

35. Generally, Java is more robust, via: Object handles initialised to null; Handles are always checked and exceptions are thrown for failures; all array access are checked for bound violations; automatic garbage collection prevents memory leaks; clean, relatively fool-proof exception handling; simple language support for multi-threading; bytecode verification of network applets.

Implementation of ACM programming fundamentals course in Java

Many institutions still teach C++ as the language for the first programming course. However, the programming language is just a tool for the course. The main objective of the course is to teach problem solving rather than the language itself. Lecturers are reluctant to change to Java thinking that Java is harder than C++, or they do not want to spend the time to learn the new language. Taking into account the amount of time it takes from the course to make the student understand pointers in C++, it is more practical to use Java than C++. This can allow the lecturer to concentrate on the major issue which is problem solving rather than the syntax of the language. Using Deitel and Deitel (2005) textbook *Java How to Program* a map was developed to link the textbook chapters to the programming fundamentals course objectives. Table 1 shows which course topics and objectives are achieved for each chapter of the textbook.

Chapter	Title	Course Topics/Objectives
1	Introduction to computers and the Internet	history and overview
2	Introduction to Java applications	programming constructs
3	Introduction to classes and objects	programming construct, programming paradigms
4	Control statements: Part I	using APIs, Algorithms
5	Control statements: Part II	and problem solving
6	Methods: A deeper look	using APIs, programming constructs
7	Arrays	data structures, Algorithms and problem solving.
8	Classes and objects: A deeper look	using APIs, object-oriented programming
9	Object-oriented programming: inheritance	object-oriented programming
10	Object-oriented programming: Polymorphism	object-oriented programming
13	Exception handling	Event-driven and concurrent programming
14	Files and streams	Programming constructs
15	Recursion	recursion
17	Data structures	data structures
23	Multi-threading	event-driven and concurrent programming

Table 1: Mapping of *Java how to program* (Deitel and Deitel, 2005) to the ACM programming fundamentals course.

Conclusion

In this paper, both the College Board Computer Science AP examination and the ACM recommendations for a first programming course in computer engineering curriculum were reviewed. A comparison between Java and C++ was also presented. Taking the ACM recommendations into account, course objectives were mapped to the contents of a popular textbook in Java. From the software engineering point of view, Java seems to be the more robust programming language than C++. Moreover, the language eliminates some of the poor design and implementation features that C++ offers. The memory management based on garbage collection appears to make Java code more robust and can allow for faster development. It is anticipated that the material presented in this study will provide engineering educators with a way to introduce programming from a problem-solving perspective rather than focusing on the programming language itself.

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Using an interactive problem-solving technique in teaching control systems

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Abstract

Interactive learning is beneficial to students as it permits many skills to be continually developed and tested as learning progresses throughout the undergraduate programme. The interactive approach enables students to continually improve their procedural, verbal, and written skills, as well as develop their communication skills. Problem solving and communication skills are very important for engineering students as in the workplace they will be required daily to communicate with people of different technical levels in different engineering fields to undertake their duties. Control systems is a complex engineering topic that contains an extended amount of mathematical formulae. Mathematical software enables the student to interactively compare a range of possible combinations and analyse the optimal solution. A popular computer package for student use for such tasks is the MATLAB software. MATLAB is a computer package that is very useful in many areas of control as it enables the user to investigate variables in the system and obtain a graphical representation of the output. Such graphical output ensures that numerous possibilities can be tested quickly and the best response selected. The software considers the system represented as an equation and many different types of graphical representations can be produced. MATLAB is useful both in industry and academia to enable the user to research and investigate models. In this paper a case study is presented that discusses how the traditional method of teaching control systems can be improved to further develop a student's abilities in electrical engineering courses by introducing an interactive teaching section using MATLAB. It was found that students became more enthusiastic and interested when they are given ownership of their learning objectives. As well as improving the student's technical knowledge, other important engineering skills are also improved by introducing this method of teaching.

Introduction

The Petroleum Institute (PI), is an English language medium engineering university (Coffman, 2003), where English is a second language for most of the students. At the PI it is recognised that it is important to ensure that the students have a continual opportunity to improve and further develop both their communication and study skills (Dwyer, Millet and Payne, 2006) as well as their understanding of technical concepts

(Stapp, 2003) that they learn in the Institute's Foundation and Core Programs. Students who are studying engineering where English is a second language are at a considerable disadvantage compared to native English speakers in that they have to both master the English language and increase their technical vocabulary in tandem. At our institution the electrical engineering programme actively seeks ways to enable the student to do this and has introduced a learner centred component into a number of the courses to motivate the student to read technical literature, analyse data they contain before producing documents and presentations on this work to their peers. In the control course (ELEG360) this principle is taken one step further by getting the student to be actively involved in the teaching and learning process (Amenkhienan and Kogan, 2004) by using computer software (Sartorius, Castellanos, Hernandez and Santana, 2005) for investigation into topics covered by the course.

The third-level feedback control course aims to teach students the following areas: system modelling through an energy flow approach and discusses modelling of electrical and mechanical systems. Feedback control design techniques using pole-placement, root locus, lead-lag, and PID compensators are presented and analysed. Although the area taught in this course is reasonably small it was decided that it would be a good idea to introduce this section before modifying the rest of the course both to gain student response and to assess the effect of this on student learning objectives.

An introduction control system course such as ELEG360 is a vital part of the undergraduate electrical engineering course, as the principles learnt are used in other areas of electrical engineering (Taraban, 2007). The basic principles of control can be highlighted using examples of everyday actions and processes which help highlight theory and applications of control. Dorf and Bishop (2005) define a control system as an 'interconnection of components forming a system configuration that will provide a desired system response'. A control system can be summarised into three basic components as illustrated in Figure 1. The input into the systems which is a variable is multiplied by the transfer function, an equation that described the action of the system, which in turn provides the output. The transfer function can be a combination of loops or a single loop and can be either a closed or open loop.

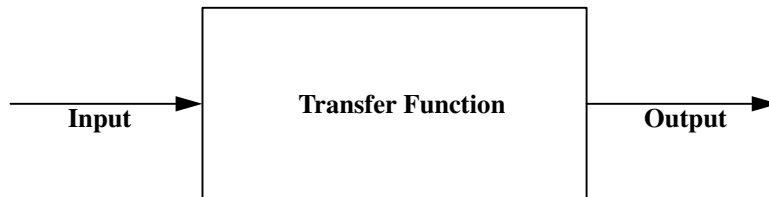


Figure 1: Basic control system.

There are two basic types of systems that are considered in the undergraduate feedback control course, open and closed loops. An open loop, as shown in Figure 2, is a system that does not have any feedback, therefore a process will happen with no modification. A simple way of describing both these systems to students at PI is by using a process they understand and use in everyday life. The system that is used is a car's steering control system. Figure 2 shows the basic components of a generic open loop

control system and the related components to the example of a car's steering in brackets. All open loop systems have the same generic components for each control system. The actuator in Figure 2 is a device which is used to cause the process to provide the output with the process being defined as the system under control. The input into the system in Figure 2 is the desired course of travel with the output of the system being the actual course of travel. In the open loop control system, as there is no feedback, there is no need for correction in this system if the car is not going in the required direction. However, no modification in this process could lead to a disastrous outcome for the driver.



Figure 2: Open loop car steering control system.

The closed loop system which is shown in Figure 3 is considered to be a superior system to use as it has feedback with the rest of the system being the same as the open loop. The feedback is taken from the output and is compared with the input of the system to provide a value which is the error of the system. If the error is zero, then the system is fulfilling all requirements and there is no modification required. However, a closed loop system is generally used when precision is needed in the system and therefore constant feedback. In such systems generally the output value varies rapidly. If, for example, the car steering control system is examined with regards to a closed loop, the sensor which produces the visual and tactile feedback is constantly modifying the direction of the car dependant on the position of the car on the road. Consequently, the faster the car is moving, the more feedback required.

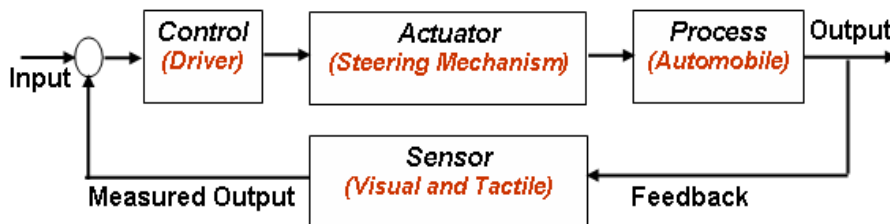


Figure 3: Closed loop car steering control system.

The traditional method of teaching control systems is by providing students with the theory, the governing equations, and the effect of changing the values in these equations. It has been found however that students find it difficult to understand the effect of changing parameters in the system, even when they have been informed of this change (Taraban, 2007).

The second order system is an important topic in the feedback control course as it shows a simple system such as an electrical RLC (resistor, inductor and capacitor)

circuit or a mechanical spring with a mass and dampened system. How the course was previously taught and how varying the teaching method to include software and student interaction improves the understanding and knowledge retention of the student as it stimulates their mind (Taraban, 2007).

The objectives of this course is to highlight how interactive teaching supports the basic theory that a student can obtain from the Internet and textbooks and ensures that a students is proactive in the learning approach which both involves them and gives responsibility for their learning outcomes with the support of the lecturer. Another objective of the course is to develop the students ability to use computer packages to investigate problems and develop there skills with specific software packages that are widely used in industry. Although not the primary objective of the course, the student's software and educational based transferable skills can be developed which is both beneficial for the students' studies and are also a useful tool if they are required to investigate projects in industry upon becoming professional engineers. Using the interactive teaching method, as opposed to traditional methods, enables the student to develop their problem-solving techniques as well as develop other skills such as communication. The control course presented in this paper aims to help the student to acquire, understand, and impart details in an efficient, confident manner together with good technical ability enabling them not only to gain more technical knowledge but to also develop personal skills.

Current teaching method of control systems

This section explains the approach of how students are currently taught control systems and highlights some of the difficulties with this method.

A second-order system can be described using the following transfer function

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}. \quad (1)$$

Here ζ is a damping ratio, ω_n the natural undamped frequency while s is a complex variable.

This transfer function is generic and obviously if dealing with real life systems the students would be provided with numerical values for analysis. The unknowns of the systems are defined in terms of damping ratio and natural undamped frequency.

The student is shown how they can relate this generic equation to a specific transfer function for a typical system such as:

$$G(s) = \frac{36}{s^2 + 2.4s + 36}. \quad (2)$$

It is discussed that they can determine the values for ω_n and ζ by comparing the generic second-order transfer function with an example in the following way.

$$G(s) = \frac{36}{s^2 + 2.4s + 36} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}. \quad (3)$$

Thus $\omega_n^2 = 36 \Rightarrow \omega_n = 6.0$ and $2\zeta\omega_n = 2.4 \Rightarrow \zeta = 2.4/(2 \times 6) = 0.2$. From these two values of ω_n and ζ the students do not appreciate the effect of different values of

the second-order transfer function on the performance of the system. Therefore, the performance equations need to be introduced. This information is given to the student by the lecturer via a short presentation.

The performance criteria for a second-order system is divided into two sections, the speed of response of the system and the characteristics of response. Each of these can be defined by equations which can calculate numerical values providing the values for ω_n and ζ are either given or can be determined.

The speed of response is characterised by (i) the rise time T_r (time to reach 100% of steady state output), and (ii) the peak time T_p (time to reach maximum overshoot) with peak time defined as

$$T_p = \frac{\pi}{\omega_n \sqrt{1 - \zeta^2}}. \quad (4)$$

The characteristics of response by the per cent overshoot (PO) defined by

$$\text{PO} = 100 \exp\left(\frac{-\zeta\pi}{\sqrt{1 - \zeta^2}}\right), \quad (5)$$

and the settling time (T_s)

$$T_s = 4T = \frac{4}{\zeta\omega_n}, \quad (6)$$

which is determined experimentally. The values for ω_n and ζ determined from the previous numerical example, can be used in the transfer function given by equation (2) with numbers to calculate the performance of this particular system. Table 1 shows the characteristics of the transfer function as a function of the following control variables.

$G(s)$	ω_n	ζ	T_s	T_p	PO
Numerical value	6.0	0.2	3.33	0.54	25.67%

Table 1: $G(s)$ characteristics used for equation (2).

The values for percentage overshoot, settling time, rise time, and peak time provide the information about this particular system and can be used to compare against a graphical plot of the system which has a unit step input placed into the system which is shown in Figure 4. Unfortunately, these values do not tell the student the responses they could expect from different systems. Although the lecturer could advise the students on how varying ω_n and ζ will affect the performance of the system, the students generally do not understand this but rather take it as another piece of information to be learnt and generally do not retain the relationship of the systems transfer function and performance.

Why change the teaching method

In the interactive classroom environment there are many simple activities that can involve the student such as getting the student to work through worked examples on the

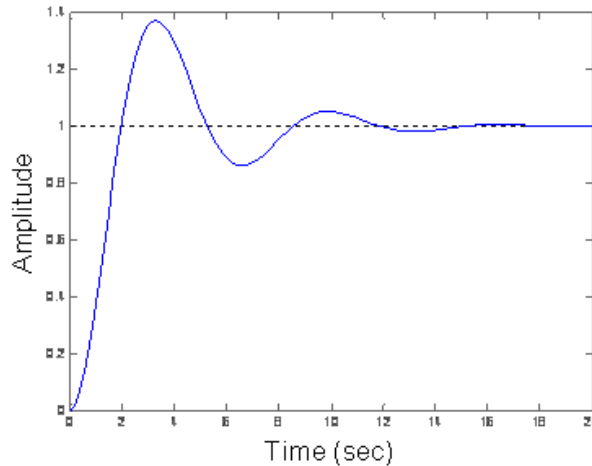


Figure 4: Numerical example of a step on a transfer function.

board, answering questions, or getting them to prepare and deliver short presentations on a given topic they have been researching. It is also interesting to initiate debate and give the students the opportunity to answer questions raised by each other. As outlined by Biggs (2003), this can provide evidence of deeper learning taking place. Initially it is time consuming due to the slower pace of imparting information but it ensures that the lecturer can continually assess the level of a student's technical and language ability. This interactive learning is only really suited to small class sizes (maximum of sixteen students per class) otherwise the experiment could become unruly. Interactive teaching takes some of the responsibility of learning away from the lecturer whose role is more that of a facilitator than an educator in this case (Brockbank and McGill, 1998). It also gives the student ownership of their learning objectives (Biggs, 2003), which is good as the students can measure their knowledge and ability against their peers and hopefully take more pride in the projects to be completed. This interactive approach develops confidence in the students.

The students, as with the traditional methods of teaching, are given the generic second-order equation and the performance equations that are linked to this transfer function of the system to the output. The interactive teaching method (Taraban, 2007) is then applied to this course, so instead of giving the students different transfer functions on which to undertake calculations to find the performance of the system using a programmable computer, the students are set an assignment to be completed in class and at home. MATLAB is a tool that is becoming extremely popular with engineering educators to develop students computer skills that can then be used to support traditional electrical engineering courses (Wallin, Carlsson, Ross and Gaidi 2005; Zhang, Adams and Burbank, 2005). The assignment is to use the software MATLAB to determine the effect of varying the values in the second-order transfer function on the performance of the system. Simulating these results enables the student to gain a better

understanding of the concepts that have previously eluded them (Goh, Tan and Tang, 2005). The students are asked to vary one value, place a unit step into the system and consider the output and how it changes. After they reach a conclusion, they are asked to vary the other values and again describe the effect on the system performance. Students are advised that they are to produce both a two page report that summarises the results and to give a presentation to their class defining the results they obtained.

After the above task has been defined for the students, if they are not already aware of the MATLAB software, a small introduction session will be completed to provide students with the ability to complete the given task. Each student writes a MATLAB program to investigate the transfer function and the system performance with the support of the lecturer. Once this is completed, then responsibility is entirely handed over to the students to investigate and conclude their results. The results shown in figures 5 and 6 are typical of what was obtained by students. From these results they can draw their own conclusions on how varying the variables of the transfer function affect the system performance. However, it is better if they plot several graphs on one plot rather than many separate plots as it is easier to arrive at a conclusion. In Figure 5 it can be easily observed that varying ω_n and keeping ζ constant will change the settling time. Figure 5 shows that increasing ω_n will decrease the time which it takes the system to reach its steady state.

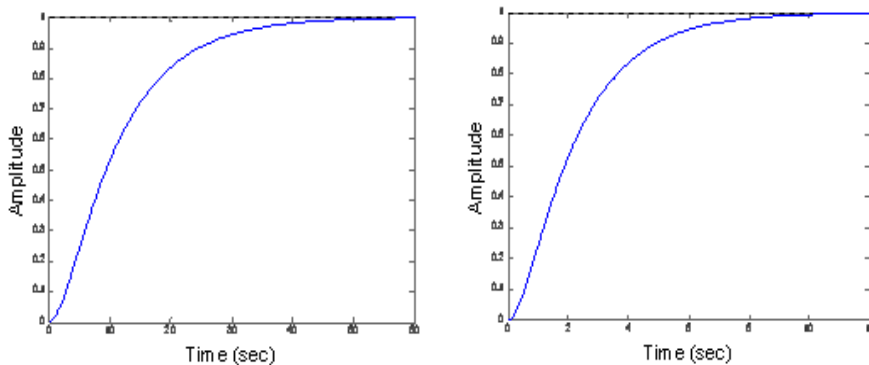


Figure 5: Step responses for different values of ω_n and a fixed value of ζ . Here $\zeta = 1.2$. Left, $\omega_n = 0.2$. Right, $\omega_n = 1.0$.

Figure 6 shows the difference in performance of the system as ζ is varied with ω_n held constant. As ζ is increased from 0.2 to 0.8 through 0.5 it can be seen that all of the performance criteria of percentage overshoot, settling time, rise time and peak time are all reduced. However, when ζ is varied between 0.8 and 1.2 it can be seen that the settling time and rise time increase again although the other performance criteria remain decreased. After obtaining their results students produce an assignment and present their results to their class mates who ask them questions and discuss their ideas with the facilitation of the lecturer.

Having reached their conclusions, the students are asked to include in the two page report a second-order system and explaining how varying the values of the transfer

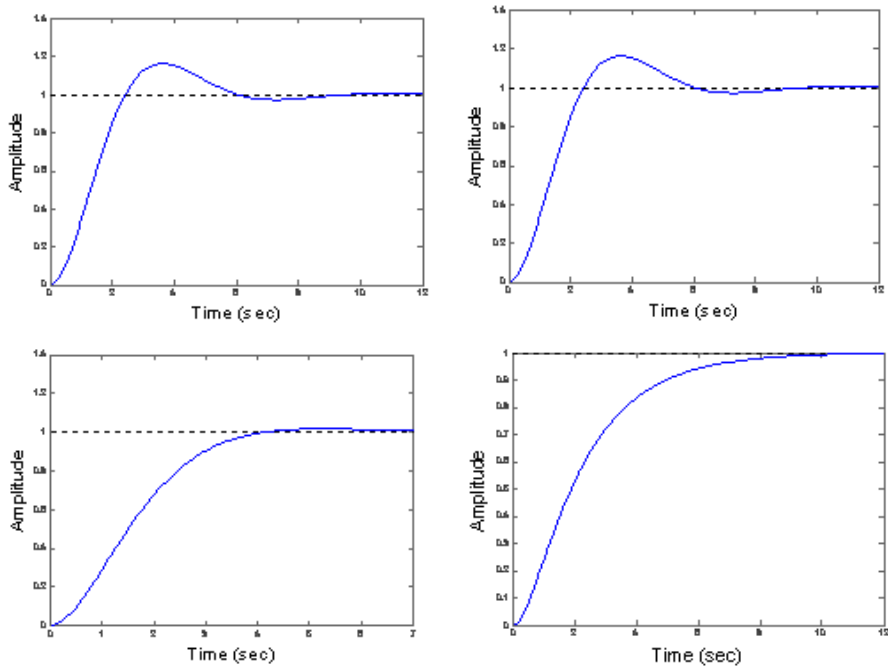


Figure 6: Step responses for different values of ζ and a fixed value of ω_n . Here $\omega_n = 1.0$. Top left, $\zeta = 0.2$. Top right, $\zeta = 0.5$. Bottom left, $\zeta = 0.8$. Bottom right, $\zeta = 1.2$.

function would affect the performance of the system. After the parametric investigation in MATLAB, this procedure was used to summarise the results of the students. As well as the written report, students are asked to present their findings in class. Incorporating communication skills in this way allows for the continual development of such skills (Biggs, 2003). Students should be keen to expand these skills once it is explained that this will help them progress in their engineering careers, as it is vital for a good engineer to be able to communicate ideas clearly and effectively with other colleagues in the business world to ensure either funding or approval to complete a project is obtained (Dulevicius and Nagineviciene, 2005; Riemer, 2002; Boiarsky, 2004). To achieve this level of confidence necessary skills need to be developed through interaction at every opportunity. The skills the students also learn in MATLAB are vital as this is a tool widely used in industry (Zhang, Adams and Burbank, 2005).

Figure 7, and the following discussion, is an example of a submitted student paper for course work assessment. The paper and presentation a student produces summarises the effect of varying the two variables of a second-order system on a system's performance. Generally the students divided the paper and presentation into two areas: section A which is considered the step responses of the system which varies ζ and keeps ω_n constant and section B which varies ω_n and keeps ζ constant. After the students produce the responses they then analysed these responses and conclude how varying

one of the variables affected the system performance. Figure 7 and the conclusion describing this figure shows section A of a student's project. Section B is not included as the layout and information is similar.

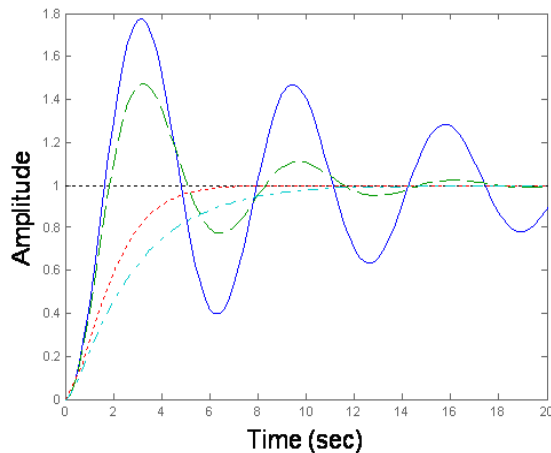


Figure 7: Step responses of a system for different values of ζ and a fixed value of ω_n .

The students summarise and conclude from the step response that when they vary ζ and keep ω_n constant it affects the performance of the system in the following ways: (i) rise time increases as ζ decreases, (ii) peak time increases as ζ decreases, (iii) per cent overshoot increases as ζ decreases, and (iv) settling time increases as ζ decreases. The student can therefore conclude the following.

- The system is considered to be underdamped if $\zeta < 1$. An underdamped system is defined as a system that will oscillate repeatedly before coming to rest.
- A critically damped system is defined as a system that just fails to oscillate and comes to rest in the shortest possible time. If $\zeta = 1$ the system is considered to be critically damped and this is the ideal result.
- Although an overdamped system has no oscillations, it takes a longer time to come to rest than the critically damped system. The system becomes overdamped if $\zeta > 1$.

Conclusion

In this paper it is shown that although the traditional method of teaching an electrical feedback course, while effective, can be improved to ensure student is both more involved in the learning process and is better able to understand how the concepts of changing variable affect a system's output. A case study on interactive teaching of control theories to undergraduate students was presented. It was shown that changing the

teaching method enables the students to improve not just their technical knowledge but also their skill in both communication and software and develop their ability to read, understand and investigate technical subjects at an advanced level. Students were more enthusiastic and interested in this topic area when implement in other areas of the course as it allowed them to take ownership of learning and understanding this topic area. It is also hoped that the method described here translates to an improvement in a student's overall performance not only in this but subsequent higher-level courses.

Due to the success of implementing this interactive teaching method at PI, with the students in the Feedback Control courses, as well as other electrical engineering courses, education could be improved by the introduction of this interactive teaching method. Also more student based investigation could be used to enhance the students' ability to review and understand basic theories giving the student more responsibility for the learning objectives of their course.

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Numerical solution of linear systems using a macro program

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Abstract

The Gauss–Seidel iterative method for solving linear systems has many applications in circuit analysis and in the numerical solution of boundary value problems. For large systems with a high percentage of zero entries, this method is efficient in terms of both computer storage and computational time. The Gauss–Seidel method is easy to apply and can be implemented using a personal computer and a spreadsheet program. In this paper a 123 macro program is used to solve linear systems using the Gauss–Seidel iterative method.

Introduction

Electronic spreadsheets such as Lotus 123 have many applications in numerical methods. Through user ‘macros’, spreadsheets can function in the same way as programs written in conventional programming languages. They can be used to solve numerical problems and to graph and plot functions. Data can be easily entered, especially for algorithms that are adaptable to a table format. Spreadsheet programs are a fast and convenient way to repeat a large number of calculations in response to some changes in the input data. One of the main advantages of using spreadsheet programs is being able to visualise the output as soon as results start to emerge. It has been shown that spreadsheets can be used to simulate the solution of advanced multi-dimensional engineering problems (Eid, 1987; Peabody, Nyberg and Dunford, 1987; Hart, 1989; Wong, 1993). Unlike the approach adopted by Eid (1987), Peabody, Nyberg and Dunford (1987), Hart (1989) and Wong (1993), where the solutions consisted of a number of steps which the user had to execute, the approach employed in this paper proposes a solution which is executed in a single 123 macro program.

This paper describes how one can use a spreadsheet program to solve an $n \times n$ system of linear equations using a Gauss–Seidel iterative method. Emphasis is placed on experimenting with the algorithm of the method using a spreadsheet and providing engineers with better alternative tools which can be used to enhance their understanding of the numerical methods concerned.

The 123 macro program presented in this paper has been extended to give a new scientific visualisation approach for experimenting and exploring the range of applicability of the Gauss–Seidel iterative method which has a wide variety of physical applications. A clear step-by-step explanation of the mechanism behind the algorithm of the method is given. By placing a strong emphasis on a clear screen-based unfolding of the algorithm, engineers can gain a better grasp of the inner workings of the numerical method. The program is applied to sample problems in electrical circuit simulation.

The Gauss–Seidel iterative method

The algorithm of the Gauss–Seidel iterative method is well known and can be found in any numerical analysis text book (see, for example, Kharab and Guenther, 2006), with the method applied as follows. Consider a 3×3 linear system:

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 &= b_1 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 &= b_2 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 &= b_3 \end{aligned} \quad (1)$$

where the diagonal terms a_{11} , a_{22} , a_{33} are all assumed non-zero. The iterative scheme begins with solving each equation in (1) for one of the variables, choosing, when possible, to solve for the variable with the largest coefficient:

$$\begin{aligned} x_1 &= u_{12}x_2 + u_{13}x_3 + c_1 \\ x_2 &= u_{21}x_1 + u_{23}x_3 + c_2 \\ x_3 &= u_{31}x_1 + u_{32}x_2 + c_3 \end{aligned} \quad (2)$$

where $u_{ij} = -a_{ij}/a_{ii}$, $c_i = b_i/a_{ii}$, $i, j = 1, 2, 3$.

Let $x_1^{(0)}$, $x_2^{(0)}$, $x_3^{(0)}$ be an initial approximation of the solution. The k th approximation is generated by writing the system (2) in the form

$$\begin{aligned} x_1^{(k)} &= u_{12}x_2^{(k-1)} + u_{13}x_3^{(k-1)} + c_1 \\ x_2^{(k)} &= u_{21}x_1^{(k)} + u_{23}x_3^{(k-1)} + c_2 \\ x_3^{(k)} &= u_{31}x_1^{(k)} + u_{32}x_2^{(k)} + c_3 \end{aligned} \quad (3)$$

In algorithmic form $x_i^{(k)}$ may be written as follows:

$$x_i^{(k)} = \frac{-\sum_{j=1}^{i-1} (a_{ij}x_j^{(k)}) - \sum_{j=i+1}^n (a_{ij}x_j^{(k-1)}) + b_i}{a_{ii}}, \quad i = 1, \dots, n. \quad (4)$$

The iterative process consists on inserting the initial approximation into the right-hand sides of (3) to obtain a new approximation. The resulting new approximations for the x 's are substituted into the right-hand sides of (3) and the process is repeated keeping in mind that the newly-computed components of the $\mathbf{x}$ vector are always used as soon as they are obtained. The process is terminated when a convergence criterion is

satisfied. One commonly used stopping criterion, known as the relative change criteria, is to iterate until:

$$\max \left| \frac{x_i^{(k)} - x_i^{(k-1)}}{x_i^{(k)}} \right| \quad \text{with} \quad \mathbf{x}^{(k)} = (x_1^{(k)}, \dots, x_n^{(k)})^T, \quad (5)$$

is less than a prescribed tolerance $\epsilon > 0$.

123 Macro program

The 123 macro program given in the Appendix solves an $n \times n$ system of linear equations using the Gauss–Seidel iterative method. The 123 macro is written in the range IA10...ID83. Some comments are given in the left-hand side of the macro range.

Input data for Gauss–Seidel method consists on the augmented coefficient matrix A , the initial approximation $\mathbf{x}^{(0)}$, the number of rows N , the tolerance EPS used in the convergence test and the maximum number of iterations ITMAX allowed. Figure 1 illustrates how these data are entered, with the computational module for equation (4) shown in Figure 2.

A	B	C	D	E	F	G	H
1		THE GAUSS-SIEDEL ITERATIVE METHOD					
2							
3	Comments: Enter the augmented Matrix A(N,N+1) starting at cell C8; the initial solution vector						
4	Xo in column B starting at cell B8; EPS, the tolerance value in cell E6; ITMAX, the maximum						
5	of iterations, in cell H6 and the # of rows N of the matrix A in cell D6.						
6	ITER #	N =	5	EPS =		ITMAX =	
7	Rows	Xo	A(I,1)	A(I,2)	A(I,3)	A(I,4)	A(I,5)
8	1						
9	2						
10	.	Vector	Augmented Matrix				
11	.						
12	.						
13	N						

Figure 1: Input data for the Gauss–Seidel method.

Model problems

Electrical circuit simulation is a topic of considerable interest to integrated circuit design and involves solving numerically a system of linear equations. Due to round-off errors, direct methods become less efficient than iterative methods when applied to large systems. For this reason, the Gauss–Seidel iterative method is commonly employed in circuit simulation.

Electronic circuits

A frequently encountered application for the solution of linear systems is the analysis of electronic circuits consisting of frequency-invariant elements. An example of such circuits is the network consisting of independent voltage sources and lumped resistors shown in Figure 3.

A	B	C	D	E	F	G	H	I
6	ITER #	N =	5	EPS =		ITMAX =		
7	Rows	Xo	A(l,1)	A(l,2)	A(l,3)	A(l,4)	A(l,5)	A(l,6)
8	1							
9	2							
10	.	Vector	Augmented coefficient Matrix					
11	.	(0)	Range M					
12	N	X						
13	Error	Iter. #	0	1	2	...		
14								
15	x1 =	@INDEX(X,0,0)						
16	x2 = Range	...	(1)	(2)	(3)		(k+1)	Range
17	...	X →	@INDEX(X,0,l)	X	X	X	...	X ← XNEW
18			...					
19			...					
20			@INDEX(X,0,N-1)					
21							Computed using Eq. (5)	
22								
23			(k)					
24			X					
25								
26			(k+1)					
27			$X_i = @INDEX(M,N,l-1) - @INDEX(X,0,1) * @INDEX(M,0,l-1) - ... - @INDEX(X,0,N-1) * @INDEX(M,N-1,l-1)$					
28								

Figure 2: Computational module of equation (4).

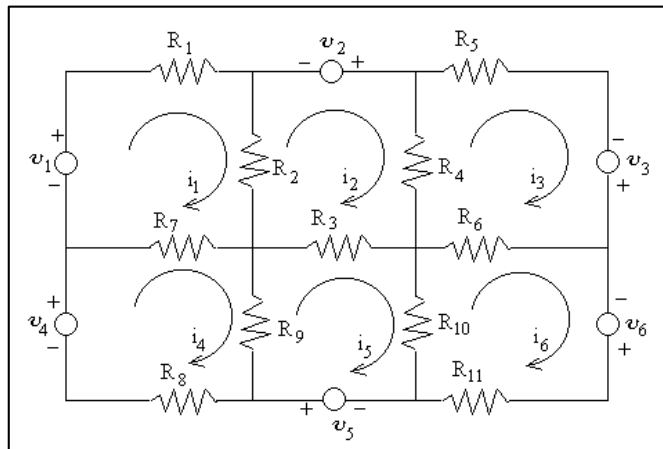


Figure 3: Electrical circuit resistance network.

The analysis of such a network requires the determination of the values of the mesh current i_k for given values of the voltage sources and the resistors. By applying Kirchhoff's voltage law around each mesh in Figure 3, the following set of simultaneous equations are obtained:

$$\begin{aligned}
 r_{11}i_1 + r_{12}i_2 + 0i_3 + r_{14}i_4 + 0i_5 + 0i_6 &= v_1 \\
 r_{21}i_1 + r_{22}i_2 + r_{23}i_3 + 0i_4 + r_{25}i_5 + 0i_6 &= v_2 \\
 0i_1 + r_{32}i_2 + r_{33}i_3 + 0i_4 + 0i_5 + r_{36}i_6 &= v_3 \\
 r_{41}i_1 + 0i_2 + 0i_3 + r_{44}i_4 + r_{45}i_5 + 0i_6 &= v_4 \\
 0i_1 + r_{52}i_2 + 0i_3 + r_{54}i_4 + r_{55}i_5 + r_{56}i_6 &= v_5 \\
 0i_1 + 0i_2 + r_{63}i_3 + 0i_4 + r_{65}i_5 + r_{66}i_6 &= v_6
 \end{aligned}$$

where the coefficient r_{ij} are defined as follows:

r_{ii} = total resistance that is present in the i th mesh.

$r_{ij}(i \neq j)$ = negative of the resistance that is common to both the i th and the j th meshes.

The 123 macro program is used to solve the linear system for: $R_1 = 2, R_2 = 4, R_3 = 5, R_4 = 6, R_5 = 3, R_6 = 5, R_7 = 2, R_8 = 4, R_9 = 5, R_{10} = 9, R_{11} = 10; v_1 = 5, v_2 = 10, v_3 = 12, v_4 = 4, v_5 = 15, v_6 = 20$. The corresponding system to these data is shown in Figure 4 where the augmented matrix A is defined by the range C8...H13, EPS = 10^{-3} and ITMAX = 40.

A	A	B	C	D	E	F	G	H	I
6	ITER #		N =	6	EPS =	1.00E-03	ITMAX =	40	
7	Rows	Xo	A(I,1)	A(I,2)	A(I,3)	A(I,4)	A(I,5)	A(I,6)	...
8	1	4	8	-4	0	-2	0	0	5
9	2	4	-4	15	-6	0	-5	0	10
10	3	4	0	-6	14	0	0	-5	12
11	.	4	-2	0	0	11	-5	0	4
12	.	4	0	-5	0	-5	19	-9	15
13	.	4	0	0	-5	0	-9	24	20

Figure 4: Input data for the electronic circuit.

Figure 5 presents the output of the 123 macro for the electronic circuit. The vector solution is contained in the range D26...D31, obtained after eight iterations. One should note that as the 123 macro runs, results for each iteration are shown on the screen and the error $\frac{|\mathbf{x}^{(k)} - \mathbf{x}^{(k-1)}|}{|\mathbf{x}^{(k)}|}$ located in the range B17...B22 is updated after each iteration. To be able to execute each macro instruction at the user's request, one can use the STEP MODE option by pressing ALT-F2 and choosing STEP.

Inverted driving a series of resistors

A particularly common circuit in circuit simulation is an inverter driving a series of resistors given in Figure 6. The KLC equation for the circuit, approximating the inverter's output as a one-volt voltage source, are

A	B	C	D	E	F	G	H	I	J	K
6	ITER #	8	N =	6	EPS =	1.00E-03	ITMAX =	40		
7	Rows	Xo	A(I,1)	A(I,2)	A(I,3)	A(I,4)	A(I,5)	A(I,6)	...	
8	1	4	1	-0.5	0	-0.25	0	0	0.625	
9	2	4	-0.26667	1	-0.4	0	-0.33333	0	0.666667	
10	3	4	0	-0.42857	1	0	0	-0.35714	0.857143	
11	.	4	-0.18182	0	0	1	-0.45455	0	0.363636	
12	.	4	0	-0.26316	0	-0.26316	1	-0.47368	0.789474	
13	.	4	0	0	-0.20833	0	-0.375	1	0.833333	
14										
15	Error	Iter. #	0	1	2	...				
16										
17	x1 =	0.000982	4	3.625	3.618561	3.843573	3.842537	3.831546	3.823412	3.817869
18	x2 =	0.000787	4	4.566667	4.873283	4.873951	4.85789	4.845733	4.837419	4.831795
19	...	0.000591	4	4.242857	4.179568	4.161476	4.149813	4.141902	4.136553	4.132939
20		0.000818	4	2.840909	3.127726	3.122246	3.110402	3.102184	3.09664	3.092897
21		0.000614	4	4.633573	4.531511	4.50587	4.492186	4.483243	4.477226	4.473165
22		0.000456	4	3.454852	3.403393	3.390009	3.382448	3.377446	3.374075	3.371799
23										
24			The method converges after				8 iterations to			
25										
26			x1 =	3.814122						
27			x2 =	4.827996						
28			...	4.130498						
29				3.09037						
30				4.470422						
31				3.370262						
32										

Figure 5: Output data for the electronic circuit.

$$\begin{aligned}
 0.01x_1 + 10.0(x_1 - x_2) &= 0.01 \\
 10.0(x_2 - x_1) + 1.0(x_2 - x_3) &= 0 \\
 1.0(x_3 - x_2) + 10.0(x_3 - x_4) &= 0 \\
 10.0(x_4 - x_3) + 1.0(x_4 - x_5) &= 0 \\
 0.01x_5 + 1.0(x_5 - x_4) &= 0
 \end{aligned}$$

The corresponding augmented coefficient matrix of the system is shown in Figure 6 along with the starting vector $\mathbf{x}^{(0)} = [50, 50, 50, 50, 50]^T$.

Figures 7 and 8 shows the input and output of the 123 macro for the inverter driving a series of resistors. Columns D, E, F, ... starting at row 16 in 8 contain the solution vectors at iteration 1, 2, 3 ... respectively. The error vector shown in range B16... B20 represents the error obtained in the last iteration where $\frac{|\mathbf{x}^{(k)} - \mathbf{x}^{(k-1)}|}{|\mathbf{x}^{(k)}|} = 0.0003$ and the solution vector is contained in the range D24... D28.

A	A	B	C	D	E	F	G	H	
6	ITER #		N =	5	EPS =	5.00E-04	ITMAX =	40	
7	Rows	Xo	A(I,1)	A(I,2)	A(I,3)	A(I,4)	A(I,5)	A(I,6)	...
8	1	0.5	10.01	-10	0	0	0	0.01	
9	2	0.5	-10	11	-1	0	0	0	
10	3	0.5	0	-1	11	-10	0	0	
11	.	0.5	0	0	-10	11	-1	0	
12	.	0.5	0	0	0	-1	1.01	0	

Figure 6: Inverter driving a series of resistors.

A	A	B	C	D	E	F	G	H	
6	ITER #		N =	5	EPS =	5.00E-04	ITMAX =	40	
7	Rows	Xo	A(I,1)	A(I,2)	A(I,3)	A(I,4)	A(I,5)	A(I,6)	...
8	1	0.5	10.01	-10	0	0	0	0.01	
9	2	0.5	-10	11	-1	0	0	0	
10	3	0.5	0	-1	11	-10	0	0	
11	.	0.5	0	0	-10	11	-1	0	
12	.	0.5	0	0	0	-1	1.01	0	

Figure 7: Input data for the inverter.

How to run the 123 macro

Once all the macro keystrokes shown in the Appendix are copied, the macro can be names by positioning the cell pointer on the top cell of the macro and then use the command /rnc to enter /A. The macro can now be run by pressing the combination ALT-A.

Conclusion

A spreadsheet program has been used to find the numerical solution of a linear system of equations using the Gauss–Seidel iterative method. Sample models used in the paper have demonstrated the power spreadsheets can have in the completion of engineering calculations. The combined computational and graphical power of spreadsheets allows for quick exploration of the numerical solution. Data can be easily entered which allow the investigator to explore the variations in the numerical solutions and the range of applicability of the algorithm. The use of spreadsheet programs can enable engineers

A	B	C	D	E	F	G	H	I	J
6	ITER #	7	N =	5	EPS =	5.00E-04	ITMAX =	20	
7	Rows	Xo	A(I,1)	A(I,2)	A(I,3)	A(I,4)	A(I,5)	A(I,6)	...
8	1	50	1	-0.999	0	0	0	0.0999	
9	2	50	-0.90909	1	-0.09091	0	0	0	
10	3	50	0	-0.09091	1	-0.90909	0	0	
11	4	50	0	0	-0.90909	1	-0.09091	0	
12		50	0	0	0	-0.9901	1	0	
13									
14	Error	Iter. # 0	1	2	...				
15									
16	x1 =	0.000444	50	50.04995	50.09531	50.13689	50.1753	50.20735	50.2341
17	x2 =	0.000372	50	50.04541	50.08702	50.12547	50.15756	50.18434	50.20669
18	...	0.0003	50	50.00413	50.01132	49.98016	49.9542	49.93258	49.91458
19		0.000306	50	50.00375	49.96563	49.93386	49.90741	49.88537	49.86703
20		0.000306	50	49.50867	49.47092	49.43947	49.41327	49.39146	49.37329
21									
22			The method converges after			7	iterations to		
23									
24			x1=	50.25643					
25			x2=	50.22536					
26			...	49.8996					
27				49.85175					
28				49.35817					
29									

Figure 8: Output data for the inverter.

to explore and experiment with many mathematical topics that have a visual aspect to them, without having to become involved in lengthy calculations and the drawing of many graphs.

Acknowledgement

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Appendix

List of principal variables used in the 123 Macro shown in Figure 9.

$X0$ = Range containing the initial approximation.

X = Range containing the current approximation to $\mathbf{x}$.

$XNEW$ = Temporary storage location for $\mathbf{x}$.

$$ERR = \max \left| \frac{x_j^{(k)} - x_j^{(k-1)}}{x_j^{(k)}} \right|.$$

$A = n \times (n + 1)$ augmented coefficient matrix.

I, J, K = Indices, N = Number of simultaneous equations, n .

	HY	HZ	IA	IB	IC		HZ	IA	IB	IC	ID	IE	IF	IG
10	Move the cursor	A1	(HOME)(D 25)(BLANK B6)~			49								
11	Set screen display off		(WINDOWSOFF)~			50	Check for zero		(LET IC1,@INDEX(A,I,1,1))~					
12	Reset all variables		/rm~rmcA-IA10~			51	diagonal elements.		(IF IC1=0)(GOTO)X~(D N+1)(R)Algorithm fails, a(k,k)=0,(QUIT)					
13	Create the variable N		/rmcN-D6~			52	Loop 2		(FOR J,1,N+1,1,IC59)					
14	Set IE1=0		(LET IE1,0)~			53			(RETURN)					
15	Move cursor to C8		(GOTO)C8~			54								
16	Name Matrix A		/rmcA~(R N)(D N,1)~			55	Normalize diagonal		(GOTO)A~(D I-1)(R J-1)					
17	Erase range of output		(L 2)(D N)(R 46)(D 100)~			56	elements of the		(LET ID2,@INDEX(A,J,1,1))~					
18	Move cursor to B8		(GOTO)B8~			57	matrix.		+ID2/IC1~r/r~					
19	Create the variables:		/rmcX0~(D N,1)~			58			(RETURN)					
20	X0, K, I, and J		/rmcX-IA1~rmcI-IA2~			59								
21			/rmcJ-IA3~			60			(LET IC2,0)~					
22	Set screen display on		(WINDOWSON)~			61	Loop 4		(FOR I,1,N,1,IC67)					
23			(GOTO)A~(D N+1)(L			62			/cX-XNEW~					
24	Error~(R)Iter. #	0~(R)1~(R)2~(R)A~				63			/rmcXNEW~(R)~					
25	Output statements		(L 4)(D			64	st X(I) for convergence		(IF IC2<F6)(LET IE1,1)~(FORBREAK)~					
26			~r~c~(R 6)~			65			(RETURN)					
27			(L)J)(D)*x1 ~-(D)*x2 ~-(D)~			66								
28	Create the variables		(UP 2)(R 2)/rmcX~(D N,1)~			67			(LET IC1,@INDEX(X,0,1,1))~					
29	X, XNEW and ERR.		(R)/rmcXNEW~(L 2)/mcERR~			68			(GOTO)X~					
30			/cX0-X~			69			(D I-1)~					
31	Move the cursor to A6		(GOTO)A6~			70			(LET ID2,@INDEX(A,N,1,1))~					
32	Loop 1		(FOR I,1,N,1,IB50)			71	Loop 5		(FOR K,1,N,1,ID79)					
33	Loop 3		(FOR B6,1,H6,1,IB60)			72			+ID2~r/r~					
34			(GOTO)X~(END)(D 2)~			73			(LET ID4,@ABS((@INDEX(X,0,1,1)-IC1)/@INDEX(X,0,1,1)))~					
35			~r~c~(R 5)~(D			74	Write the error		(LET ERR,ID4)~rmcERR~(D)~					
36	Output statements		(IF IE1=0)(BRANCH IA41)			75			(IF I=N)/rmcERR~(UP N)~					
37			The method converges after~(R 3)			76	Find the maximum error		(IF ID4>IC2)(LET IC2,ID4)~					
38			+B6~(R)iterations to~			77			(RETURN)					
39			(L 4)(D 2)*x1 ~-(D)*x2 ~-(D)~(UP 2)(R			78								
40			(BRANCH IA46)~			79								
41			The method did not meet the Tolerance of~			80	Compute Xi		(IF K=N)(BRANCH ID83)~					
42	Write # of iterations		(D)+F6~			81			(LET ID1,@INDEX(A,K,1,1))*@INDEX(X,0,K,1))~					
43			(R)in~(R)+H6~(R)iterations~			82			(GOTO)X~(D I-1)					
44	Output statements		(L 3)(D			83			(LET ID2,ID2-ID1)~					
45			The last value of X was~(D 2)(R						(RETURN)					
46	Write the solution		/cX~(END)(D											
47			/cX0-X~											
48			(QUIT)~											

Figure 9: Listing of the 123 Macro program.

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Robotic kits as a platform for learning

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Abstract

In a world full of technological innovations and ideas there is a need to raise an interest in science and technology. Edutainment (entertaining and instructive) robotics is an excellent vehicle for providing technology education for the general public, for example, school pupils and parents alike. Educational robotics, the use of robotics as a hands-on learning environment, is becoming increasingly common for several reasons. For example, recent research on learning theory indicates that the learning environment should be managed in such a way that pupils are encouraged to set their own goals, actively gather meaningful information, and monitor and evaluate their own learning. In addition, robotic kits are becoming more accessible and affordable. Technology literacy for all on the one hand and continuous demand for skilled technology engineers and workers on the other hand, poses a challenge to education systems worldwide. In recent years effort has been made to integrate technology into all levels of the school curriculum. The work presented here introduces one possible approach to familiarise secondary school pupils with high-level technology using a mobile robot as the principal tool in the curriculum. It looks at ways to incorporate robotics into the basic education system in Oman.

Introduction

A convincing case can be made for the urgency of educational reform (in particular science education) in the region. This educational reform is needed to achieve economic development (Ramirez, Luo, Schoter and Meyer, 2006), to cope with the ever-changing nature of today's technology (Kolberg and Orlev, 2001; Heer, Traylor, Thompson and Fiez, 2003; Moore, 2003; Traylor, Heer and Fiez, 2003; Verner and Hershko, 2003). In addition, educational reform is needed to meet the demands of our societies for creative engineers and skilled technicians (Resnick, 1996). One major problem of our current educational system is the fact that learning is still looked upon as the transmission of knowledge from those who have, the teacher, to those who do not have, the pupil. New approaches are needed to present an appropriate and interesting curriculum in a way

that would engage pupils and give them insight into engineering and technology studies. Project-based learning offers a lot to educators who believe in learning through discovery via direct experience in which pupils are actively engaged in learning, and in constructing understanding and meaning. Robotics, being a multifaceted representation of modern science and technology, fits into this vision by providing a platform for learning by experimenting and playing with robotic kits that are used to build certain products to accomplish a given task. The study presented in this paper describes a framework through which robotics can be used to promote interest in the engineering profession amongst school pupils aged ten to eighteen years, as well as to provide a vehicle for project-based learning to introduce design, technology and problem solving to the curriculum.

Methodology

The learning strategy suggested in this work can be described as guided constructionism, because it suggests combining traditional constructionism (Resnick, 1996) with 'guidance' to accelerate the learning process. When robotic kits (in the form of games or design projects) for educational purposes are used whereby learners are encouraged to combine knowledge from different areas and topics to arrive at a solution or to make a decision at a certain point. Learners can observe the outcomes of 'their actions' and 'decisions' and discuss, reflect and to negotiate subsequent steps thus improving their understanding (Ostwald, 1996; Custer, Valesey and Burke, 2001; Heer, Traylor, Thompson and Fiez, 2003; Verner and Hershko, 2003). The work proposes to start the program using systems such as LEGO Mindstorms¹ (Resnik and Ocko, 1991; Resnick, Martin, Sargent and Silverman, 1996) and VEX² to incorporate robotics into the curriculum of grades six to twelve (ages eleven to eighteen) with the objective of engaging pupils through an exciting application of mathematics, computers and science. Pupils will eventually design robots from scratch once the basics are mastered. Referring to Figure 1, the pupil in this learning strategy will be asked to carry out a project (i.e. solve a problem). The pupil will start asking questions, making assumptions, initiate investigations, collect data, share ideas and perform experiments in order to define the task and later to find a solution. Pupils through interactions with the project and with each other build their own knowledge while the teacher directs, guides and manages the whole process.

The framework of this learning strategy involves the following:

1. Learning basic topics. For pupils to be able to work on their projects they will need to master a set of basic knowledge that may includes topics such as basic electronics, mechanics, and basic programming.
2. Active and cooperative learning techniques will allow pupils to take responsibility for their learning (Resnik and Ocko, 1991; Resnick, 1998; Traylor, Heer and Fiez, 2003). The instructional activity engages pupils in doing and thinking instead of passive listening.

¹Available from: <http://mindstorms.lego.com/>

²Available from: <http://www.vexlabs.com/>

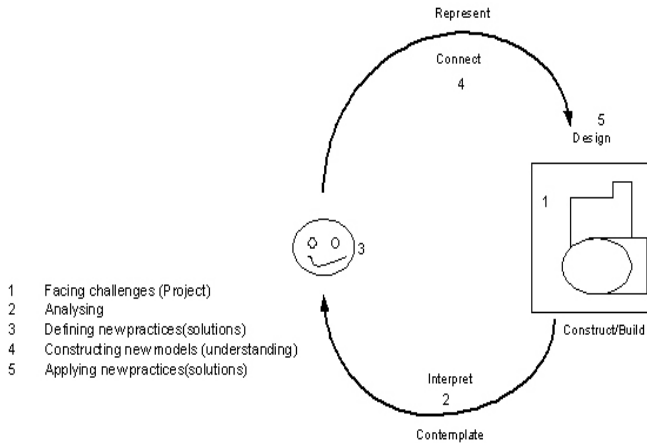


Figure 1: The learning strategy.

3. Just-in-time teaching. Instead of teaching topics in isolation, the interrelationships of topics are illustrated by presenting the necessary material as they are needed.
4. The teacher becomes a mentor who does not necessarily have all the answers nor does he or she know the absolute truth, but rather acknowledges and accommodates different learning styles and who listens while guiding and providing advise during the learning process, who helps pupils express their ideas, who introduces new concepts whenever needed, who help pupils work as a team, and who evaluate and assess the learning process.
5. Workshops and professional development will be needed for teachers not only to learn about robotics, but also to know how to incorporate this knowledge about robotics into their classrooms in an active and engaging way (Bruder and Wedeward, 2003).
6. Pupils will move from one level to the next. At first pupils will learn to build robots following guidelines and instructions from the mentor. They will then learn the use of sensors, motors, gears, pulleys, levers, etc. In the second stage pupils will experiment with robots to accomplish simple well defines tasks like following a black line using a light sensor or avoiding obstacles using a touch sensor. In the third stage pupils will move from playing with robots as toys into the broader world of robots. Pupils will learn how to build robots from scratch and to program them for games such as running a maze, following a track, robot soccer,³ fire fighting, robot de-mining, and so on. These games and design projects (see Figure 2) can empower pupils by representing unique learning opportunities for them (Flowers, 1998; Moore, 2003).

³Available from: www.robotcup.org



Figure 2: Robotic contest as a motivation for learning.

The study works on having an annual national robotic contest in which pupils from different schools will compete against one another. Pupils will be introduced as well to international opportunities available for school children for participating in various contests and competitions. Involvement of pupils in a robot contest can offer educational benefits that include (Verner and Hershko, 2003):

- (i) Preparation for the complex modern work environment by building communication skills and responsible teamwork skills.
- (ii) The contest provides a focused open-ended task that motivates pupils' creativity.
- (iii) Development of project management capabilities and professional attitudes.
- (iv) Promotion of collaborative efforts between schools and universities to develop shared curriculum and study materials.

Preliminary conclusions

The school model in which pupils are passively taught facts out of context will not help our societies to survive in this ever-changing world of knowledge. Pupils need to master fundamental skills (reading, writing, and mathematics), but they also need skills like teamwork, problem solving, lifelong learning abilities, time management, information synthesising, and the ability to use high-tech tools. With these skills pupils are able to master what they were not taught and to handle the complexities of today's ever-changing world.

The ministry of Education in Oman is currently focusing on innovating and developing the educational system in line with the country's 2020 vision and to cope with the scientific and technological advances of recent years. A basic education system has been set-up to keep pace with technological and scientific progress. This education consists of three cycles; cycle one covers years one to four, cycle two covers years five through ten, while cycle three covers years eleven and twelve at senior secondary school. New subjects such as information technology and life skills have been added to the basic education system, and more concentration is given to mathematics and science with the curriculum being more pupil-centred than the traditional system. Even though there are courses like information technology (in the new basic education system), the curriculum and the teaching practice are yet to realise that computers are not 'the technology', they are simply part of the today's technology landscape. In the authors opinion, we are still concentrating on how computers enable people to send, access, and manipulate information in one way or another, rather than moving beyond that strategy. Therefore, there is still work that needs to be done. However, this study and similar initiatives that encourage new ways of learning that are learner-centred, should be viewed upon as 'pilot studies' from which the experience gained will provide guidance in undertaking future educational system reform. A number of challenges however, need to be addressed.

- (i) Lack of teachers' experience in project-based learning presents a challenge (Frank and Barzilai, 2004; Hol-Reynolds, 2000); for teachers will tend to prefer the traditional structured approach. Furthermore, the method is rather demanding in terms of time and effort. Class management will therefore pose a challenge to teachers.
- (ii) Content and instructional design. One will need to address how to design effective learning opportunities. One will need to come up with innovations in hardware and software needed as tools to learn, teach and evaluate with.
- (iii) Assessment and evaluation methods. One will need to address how to assess what pupils learn as they engage in design and project-based learning activities (Custer, Vaseley and Burke, 2001; Frank and Barzilai, 2004).
- (iv) Expanding the involvement of parents in the education of their children will be a positive and demanding task. Along this line the project will provide workshops for parents on the use of robots as an educational tool.
- (v) Cost. There is a need to manage these kind of courses in a way that reduces cost by sharing resources between schools, time management to let different classes (group of pupils) share the same set of tools. There is also a need to produce locally made kits which are reasonable priced (Sipitakiat, Blickstein and Cavallo, 2004).

In conclusion, the work presented in this paper is just a preliminary plan with the objective to provide assistance to secondary school educators in establishing robotics programmes, provide pupils and teachers training and workshops, design robot contests that are accessible to a wide range of pupils, and to design reasonably priced robotic

kits for schools. This pilot study will also reach out to schools to have tertiary-level staff and students visit schools either for demonstration or as mentors.

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Computing

The influence of external factors on secondary teachers' intention to use and actual use of Information and Communication Technology in teaching

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Abstract

This study investigates the influence of external factors such as; age, gender, subject taught, teaching experience, the number of teaching period, qualification, level of class taught, and computer access in the classroom and computer laboratory; on Bruneian secondary teachers' intention to use and actual use of Information and Communication Technology (ICT) in their teaching. All government secondary school teachers ($N = 1040$) who taught various curriculum subjects participated in the survey research. The analysis and discussion of results revealed that teachers' class access is the only external variable that shows statistically significant prediction on intention to use. However, three external variables, namely subject taught, class access, and computer laboratory access, show significant prediction on teachers actual use of ICT in teaching. Practical implications of these findings are identified and discussed. This study indicated that there is a need to address some external factors that may influence teachers to use ICT in teaching.

Introduction

There are few studies that specifically examine the influence of external variables such as demographic characteristics on teacher computer or Information and Communication Technology (ICT) use in teaching. However, one research study involving 236 teachers from Belgium secondary schools investigated the relationship between class computer use and external variables such as sex and age; and individual teacher characteristics such as teachers' technology-related subject, general computer attitudes, attitudes toward computers in education, technological innovativeness, and general innovativeness (van Braak, 2001). With regard to sex and gender, the research findings were that sex differences were related to class use of computers and that male teachers made more use of computers in class than female teachers; age was not significantly related to the dependent class use of computer variable.

In another study, Yuen and Ma (2002) administered a questionnaire survey to 186 pre-service teachers in Hong Kong and found significant sex differences with regard

to the influence of perceived usefulness and perceived ease of use of computers on pre-service teachers' intention to use computers. In particular (i) perceived usefulness influenced intention to use computers more strongly for females than males, (ii) perceived ease of use influenced intention to use computers more strongly for females than males, and (iii) perceived ease of use influenced perceived usefulness more strongly for males than females.

Other external factors reported to have an influence on the use of ICT were reported by Williams, Coles, Wilson, Richardson, and Tuson (2000), who used questionnaire surveys involving 300 primary schools and 100 secondary schools in Scotland. They found that some of the factors inhibiting secondary teachers' use of ICT were their lack of skills, lack of familiarity with the Internet, and the lack of available of Internet access.

Czerniak, Lumpe, Haney, and Beck's (1999) survey involving 250 private and public school teachers in Ohio in America found that external factors such as availability of resources, support for use of technology, and opportunities for staff development would enhance their use of educational technology.

Most of the above studies surveyed demographic characteristics of teachers and describe their personal factors that influence their use of ICT. An accurate understanding of how the demographic characteristics of teachers may influence their thoughts about ICT use and how these thoughts influence their decisions to use ICT may be useful to motivate teachers. However, knowledge of the demographic characteristics alone may not be enough as such characteristics change with the rapid development of ICT in education, and there may also be other factors associated with the demographic characteristics that may influence use. Nevertheless, in this study, how demographic characteristics are related to teachers' use of ICT is examined.

Research question and hypotheses

This study attempted to examine how the external factors, such as age, sex, subject taught, teaching experience, teaching periods, qualification, teaching level, class access, and computer laboratory access can be used to predict and explain teachers' intention and behaviour for using ICT in their teaching. For the purpose of answering the research question, the following proposition is suggested: the external variables that predict teacher intention to use ICT consist of demographic variables. The following hypotheses are put forward to test this proposition:

Hypothesis H1: External variables positively influence teacher intention to use ICT in teaching.

Hypothesis H2: External variables positively influence teacher use of ICT in teaching.

Method

This study employed a survey research method that has been frequently used in research on information technology and computer use. A survey research method is particularly useful for generating quantitative data that can be used to establish the basis for wider generalisation. A questionnaire, the ICT in Education (ICTE) (Sallimah,

2006) was administered to obtain participants' responses to the variables under investigation. The data collected on these variables can then be studied using appropriate statistical procedures.

Participants

The setting for this study was limited to only government secondary schools in all four districts of Brunei Darussalam. While the schools differ in many ways, such as the number of computers and networking resources, staff expertise, and number of students and teachers, researching a single administrative domain (government secondary schools) under one department (secondary section of the Department of Schools) administering all secondary schools exclusively, is considered to be advantageous in terms of controlling for extraneous variables that could be confounded with other research variables.

The target population of this study consisted of secondary school teachers who are employed by the government to teach the various curriculum subjects. Participants for the study consisted of all local teachers teaching in the eighteen government secondary schools in the four districts in Brunei Darussalam. The current study assumes that by including only local teachers and excluding expatriates, the study would provide exclusive generalisation about local teachers' perceptions towards the use of ICT. Consequently, any recommendations to be suggested would suitably be based on the Bruneian context. Moreover, comparison of findings about teachers' use of ICT between Brunei and other countries would be justifiable.

All the teachers, except expatriates, in the eighteen schools (N = 1453) were given the questionnaires at their respective schools. The questionnaires were collected a week after distribution with a letter of appreciation to the school principal, acknowledging the participating teachers. A total of 1040 (72% return rate) copies of the questionnaires were returned.

ICT in education questionnaire: Reliability and validity

A structured questionnaire, what we call the ICTE questionnaire, was used as the research instrument in the current study. As most of the items in the questionnaire have been used elsewhere and have been tested for reliability and validity, in the context of that use, the content validity of the ICTE questionnaire has been assumed by making reference to those standard questionnaires.

Operationalisation of demographic variables

The following demographic variables are operationalised for the current study.

1. Age – Teacher respondents' age was operationalised by asking them to select from a series of various age groups: 18–25; 26–30; 31–35; 36–40; 41–45; and 46+.
2. Sex – Teacher respondents' sex was operationalised by asking them to indicate their sex from two choices: male and female.
3. Subject taught – Teacher respondents were asked to write the subject or subjects they taught in the school.
4. Teaching experience – Teachers' teaching experience was operationalised in terms of the number of years they have been teaching. The teacher respondents' were

asked to select from the following: 0–1 year, 2–5 years, 6–10 years, 11–15 years, and 15+ years.

5. Number of teaching periods per week – Teacher respondents were required to write the number of teaching periods per week.
6. Highest qualification: Teacher respondents were asked to indicate their highest qualification from selecting one of the following: Certificate, Diploma, Bachelor, Masters, or PhD.
7. Level of students taught – Teacher respondents were required to indicate the level of students they taught from a selection of: Lower secondary; Upper secondary; Both lower and upper secondary.
8. Access to computers – Teacher respondents' access to computers was operationalised by asking them to indicate if they have access to computers in the classrooms and computer laboratory respectively. They were required to provide a yes/no response to each.

Analysis

Hierarchical multiple regression was employed in this study as a statistical method for testing hypotheses relative to the influence of external variables on the dependent variables of the research model. Hierarchical multiple regression is a useful procedure for determining the relationships between a dependent variable and some predictor variables with the effect of other predictor variables statistically eliminated. Hierarchical multiple regression is a procedure for a covariates analysis which investigates if some critical variables contribute to a prediction equation for a dependent variable after the other predictor variables or the covariates have been eliminated from the equation. In conducting the hierarchical multiple regression, the order of entry of variables into the regression equation was determined *a priori* on the basis of theoretical rationale. In the first step, the covariates (i.e. other predictor variables) were entered into a hierarchical equation to control for their confounding influence. Then, the variables of interest were entered into the equation. The R^2 – *change* and its statistical significance assessed the proportion of variance uniquely accounted for by the predictors of interest.

Results

This study addressed the research question: *How do the demographic factors (age, sex, subject taught, teaching experience, teaching level, academic qualification, level of class, class access, and computer laboratory access) predict and explain teachers' intention and behaviour for using ICT in their teaching?* In order to answer this research question, a research proposition was suggested and the associated research hypotheses were formulated to provide statistical support to the proposition and ultimately answer the research question. The proposition posits that the external variables that predict and explain teacher intention and use of ICT consist of demographic variables. The relevant hypotheses to assess this proposition were stated earlier. Hypotheses H1 and H2 were tested using a two-step hierarchical multiple regression for testing the influence of each of the external variables on intention and use of ICT (as the dependent variables)

respectively. In the first step, all the intervening variables between external variables and the dependent variable are entered. In the second step, the external variables are entered. Table 1 and Table 2 show the results of the hierarchical multiple regression analyses for the assessment of H1 and H1. Table 3 and Table 4 show the regressions coefficients of the external variables on intention and use of ICT respectively.

Influence of external variables on Intention

Table 1 indicates that external variables explain an additional 1.5 per cent of the variance in total intention after controlling for the other intervening variables. This small but significant (at $p < 0.05$) effect of external variables on intention supports H1 that states that external variables positively influence teachers intention to use ICT in teaching.

Model	R	R^2	Adjusted R^2	Standard error of Estimate	Change Statistics				
					$R^2 - \text{change}$	F change	df1	df2	Sig. F change
1	0.495	0.245	0.238	0.96	0.245	35.003	8	863	0.000
2	0.510	0.260	0.245	0.95	0.015	1.954	9	854	0.042

Table 1: Hierarchical multiple regressions test for influence of external variables on intention.

Table 2 shows the regression coefficients of the various external variables on intention after controlling all intervening variables. Class access ($B = -0.091$; $p = 0.003$) is the only external variable that shows significant prediction on intention.

	Unstandardised coefficients B	Standardised error	Standardised coefficients B	t	Sig.
Age	-0.046	0.045	-0.067	-1.010	0.313
Sex	-0.077	0.071	-0.033	-1.085	0.278
Subject taught	0.014	0.012	0.035	1.116	0.265
Teaching experience	0.035	0.051	0.046	0.695	0.487
Teaching period	-0.055	0.073	-0.022	-0.753	0.451
Qualification	0.0003	0.041	0.000	0.009	0.993
Level of class	0.061	0.043	0.043	1.394	0.164
Class access	-0.308	0.102	-0.091	-3.022	0.003
Computer room access	-0.060	0.076	-0.024	-0.786	0.432

Table 2: Influence of external variables on intention after controlling for all intervening variables.

Influence of external variables on use of ICT

Table 3 indicates that external variables explain an additional 9.4 per cent of the variance in use of ICT after controlling for the other intervening variables. Although the

effect of external variables on use of ICT is small, it is significant at $p < 0.01$, hence supporting H2 that states external variables positively influence teachers' use of ICT in teaching.

Model	R	R^2	Adjusted R^2	Standard error of Estimate	Change Statistics				
					R^2 – change	F change	df1	df2	Sig. F change
1	0.336	0.113	0.105	0.66	0.113	13.746	8	863	0.000
2	0.455	0.207	0.191	0.63	0.094	11.246	9	854	0.000

Table 3: Hierarchical multiple regressions tests for influence of external variables on use of ICT.

Table 4 shows the regression coefficients of the various external variables on use of ICT after controlling all intervening variables. Subject taught ($B = 0.088$; $p = 0.007$), class access ($B = -0.226$; $p = 0.000$), and computer laboratory access ($B = -0.159$; $p = 0.000$) are the three external variables that show significant prediction on teachers' use of ICT in teaching.

	Unstandardised Coefficients B	Standardised error	Standardised coefficients B	t	Sig.
Age	0.016	0.030	0.038	0.553	0.580
Sex	-0.019	0.047	-0.013	-0.408	0.683
Subject taught	0.022	0.008	0.088	2.719	0.007
Teaching experience	-0.050	0.033	-0.103	-1.494	0.135
Teaching period	0.038	0.048	0.025	0.800	0.424
Qualifications	-0.028	0.027	-0.034	-1.029	0.304
Level of class	0.042	0.029	0.045	1.411	0.159
Class access	-0.487	0.067	-0.226	-7.254	0.000
Computer room access	-0.254	0.050	-0.159	-5.077	0.000

Table 4: Influence of external variables on Use of ICT after controlling for all intervening variables.

In order to identify which subjects are associated with greater use, the two variables, class access and computer laboratory access, were cross-tabulated with subject and use of ICT. Table 5 presents the results of the cross-tabulation for teachers' positive responses to all the four variables.

Previously, Table 1 showed that a total of about twelve per cent of teachers ($n = 114$) had class access to computers, and a total of about seventy-three per cent ($n = 698$) had access to computer laboratory. Table 5 shows that the teachers who had class access to computers all reported using ICT for teaching ($n = 114$). Among the teachers who had class access to computers, teachers of religious studies (19.3%), sciences (14.9%),

mathematics (14.0%), Malay language (14.0%) and computer studies (10.5%) reported more use of ICT in teaching. The above table also shows that among those who had access to computer laboratory, only about twenty-five per cent ($n = 236$) reported using ICT in teaching. Among those teachers who have computer laboratory access, teachers of sciences (18.9%), mathematics (15.7%), and religious studies (13.4%) reported more use of ICT in teaching.

Subject	Class access (valid $N = 959$)		Computer Lab access (valid $N = 951$)	
	n	% use of ICT	n	% use of ICT
Mathematics	16	14.0	111	15.7
Science	17	14.9	134	18.9
History	7	6.1	38	5.4
Geography	8	7.0	85	12.0
Malay Language	16	14.0	83	11.7
English Language	4	3.5	60	8.5
Religious Studies	22	19.3	95	13.4
Physical Education	2	1.8	16	2.3
Economics	5	4.4	36	5.1
Computer Studies	12	10.5	19	2.7
Art and Design	5	4.4	29	4.1
Sociology	0	0	2	0.3
Total	114	100	236	100

Table 5: Cross-tabulation of subject teachers' use of ICT with class access and computer laboratory access.

Discussions and conclusions

The evidence presented by the statistically supported research proposition provide answers to the research question, namely some of the external variables are able to significantly predict teacher's intention and use of ICT although the amount of increase in variances explaining intention and use of ICT respectively are small. The current study is able to show that only one external variable, class access, can significantly predict intention and three external variables, subject taught, class access, and computer laboratory access, can significantly predict use of ICT. Previous research has shown that the demographic variables have some influence on teacher use of ICT. The current study is able to show that some of these variables can be used to predict intention and explain behaviour on a theoretical basis. However, further study is required in order to improve the weak predicting and explaining power of these variables. In conclusion, the current study provides evidence that some of the external factors are able to significantly predict and explain teachers' intention and use of ICT in teaching.

Implications

The findings of this study imply that there is a need for administrators to address the external factors that influence teachers' use of ICT in teaching, in addition to other factors that may contribute to their decisions to use ICT. The teachers in this study indicated that their classroom and computer laboratory access, and the subject they taught, significantly influence their intention and actual use of ICT. Therefore, school administrators should install computers not just in the laboratory but also throughout classrooms.

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Second Life and online collaboration through peer-to-peer distributed learning networks¹

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Abstract

This paper discusses the concept of distributed learning networks and their potential for professional development and collaborative learning using the Internet in peer-to-peer networks. Many innovative distance learning environments have arisen recently thanks to remarkable developments in the ways people are now able to interact over the Internet, freely and without reliance on client-server network models. Example learning environments range from relatively flat but open-source learning and content management tools (such as Moodle and Drupal) to richer facilities integrating learning with social networking tools (such as Elgg and MySpace), and beyond (for example, Second Life).

Introduction

Use of social networking sites (and ‘beyond’) in education has been called ‘transformative’ by some, whereas others seek to ban and block them. The challenge for proponents is to gain enough experience through experimentation and critical reflection to mount principled appeals to policy-makers, who may not have grasped the transformative benefits accruing from relatively unfettered access to an evolving Internet. Dangers of forfeiting the lead in this regard include relegating students to non-competitive positions in an ever-more-wired and connected world, and stifling opportunities for educators and students to carry on conversations that would otherwise promote learning through interaction with others in the distributed learning peer-to-peer (P2P) network. Second Life illustrates here the educational potential at the cutting edge of technology in an environment tolerant of experimentation. Second Life (and its precursor, Active Worlds) have long-standing credentials as educational environments (e.g. language projects in Active Worlds; elaborate simulations and labs/museums in Second Life). I hope to suggest how educators can use such spaces in transformative ways to foster distributed learning networks, such as hosting science simulations, in an environment well integrated with Web 2.0 and the read-write Web.

¹ A prior version of this article about Second Life in language learning appeared in Stevens (2006a).

Second Life as a peer-to-peer distributed learning network

These days collaboration online is sometimes characterised in terms of ecology. Dieu, Campbell and Ammann (2006) for example argue that ‘a pedagogical approach based on P2P can support learning ecologies that both complement and transcend conventional classroom structures and practices, ultimately benefiting learners’. Stevens (2006b) addresses the concept of distributed learning networks as having to do with ‘the notion that knowledge is distributed; i.e., not resident in any one person or repository. It turns out that peer-to-peer networks are preferable to hierarchical ones, and well suited to knowledge distribution, when working through the Internet’. Stevens draws heavily on the recorded presentations of Stephen Downes, as reported for example in Wise (2006). Downes promotes the concept that distributed learning networks as expressed in wikis and other tools where collaborators work as equal entities in parallel are not only productive but remarkably self-regulating.

Second Life² is a program with some potential for letting all kinds of collaborators, and especially educators, work within and develop these concepts. Second Life is produced by Linden Labs in California and allows anyone with a fairly robust computer and an Internet connection to interact with others in a three-dimensional virtual space. Wayne MacPhail describes the experience rather well in a podcast recording.³

Second Life is a 3D virtual world you enter via software on your computer. In Second Life you’re represented by a virtual you, an avatar. Male or female, tramp, vixen, animal, average Joe or fashion plate, how your avatar looks is up to you. ... My avatar, under my mouse and keyboard command can walk, run and fly, yes, fly, through hundreds of square miles of terrain, shops, houses and nightclubs. There are lots of nightclubs. But, there are also dozens of educational and non-profit institutions, that have created storefronts and campuses, 3D versions of real campuses in Second Life. Why?

That question, which this paper sets out to answer, can be expanded into more questions. Is Second Life the up and coming harbinger of collaboration and productivity online, or a banal trap that is consuming resources and time best spent elsewhere? Is Second Life ideally matched with the open-source nature of the read-write Web and social networking, a next-stage in the level of conversations redirecting our interpersonal and societal interactions (including those in the marketplace) applauded in the Cluetrain Manifesto,⁴ or is it heading in the other direction, uncomfortably corporate and profiteering? And what if anything does this have to do with education? Reactions of educators vary with respect to benefits to education in Second Life, but most of the million or so people who inhabit its alternate universe must feel that Second Life is a virtual world with a difference, or they would not be there.

Depending on whose figures you believe, perhaps half a million unique avatars touched down in Second Life in the last two months of 2006, and that number has been growing steadily. It is not the numbers so much as what those avatars find when they get

²<http://www.secondlife.com>

³<http://www.rabble.ca/rpn/episode.shtml?x=54785>

⁴<http://www.cluetrain.com>

there, a virtual world where possibilities seem endless. Not only can you (or someone more clever than you) create the world of your choice replete with gizmos and widgets that do things, like play recordings and slide shows or provide you with utilitarian tools and information, but your avatar can defy gravity and fly at will. You can teleport from place to place, world to world, and you can ride all manner of conveyances if available. I recently sat fully clothed on a stool half-submerged at a poolside bar and had a pleasant chat with an attractive lady as fully dressed and waist deep in water as I was. In real life this lady had put on a conference at which I had been a plenary speaker. A snippet of what it is like 'in world' is captured in this cameo '[Y]esterday a cheerful Italian gave me a Babbler translator so we started teaching each other Italian and Hungarian using English as the common language, which was real fun, especially that we were figure ice-skating meanwhile.'⁵

Active Worlds: Precursor to Second Life

Second Life appears at first glance a reincarnation of Active Worlds, an avatar-based multi-user virtual environment (MUVE), developed in the mid-nineteen-nineties which once had around half a million users.⁶ It has been remarked that diminishing populations are taking the fun out of life there.⁷ However MUVE's such as Active Worlds have often been used in education as simulating environments rich in learning opportunities, for example, *The River City Project* headed by Chris Dede.⁸

Active Worlds has also been used as a virtual space to explore how communities operate. Quest Atlantis⁹ for example was presented at the 2005 WiAOC Conference¹⁰ by Dongping Zheng, Robert Brewer and Michael Young. Like the River City project, Quest Atlantis is National Science Foundation funded, and uses an Active Worlds kernel to immerse children, ages nine to twelve, in educational tasks. One of its goals is to research 'the complex variables that constitute an online learning, playing, and socially conscious experience' according to a broadside of the Center for Research on Learning and Technology at Indiana University¹¹ (see, for example, Dede, 2005).

In another such study, Peterson (2006) found that participants in Active Worlds were able to undertake a variety of tasks through target language interaction, and also employed transactional communication and interactional strategies. Task type influenced the quantity of negotiation, and the use of avatars facilitated learner interaction management during real-time, computer-mediated communication. He concludes that the learner interaction was influenced by the complex interaction of a number of variables including task type, sociolinguistic factors, context of use, and the mix of technical affordances provided by Active Worlds.

⁵Posted 27 November 2006 at http://groups.yahoo.com/group/evonline2002_webheads/message/14030

⁶According to <http://awportals.com>

⁷<http://forums.activeworlds.com/archive/index.php?t-5429.html>

⁸<http://muve.gse.harvard.edu/rivercityproject/index.html>

⁹<http://atlantis.crlt.indiana.edu>

¹⁰<http://wiaoc.org>

¹¹<http://crlt.indiana.edu/research/qa.html>

Why the time is right for Second Life

As we see, Second Life is not particularly new in concept, but follows on work most recently developed in Active Worlds. The look and feel of both worlds is, on first arrival ‘in world’, strikingly similar. In both, you appear in a three-dimensional fantasy land as an avatar in the company of other avatars. You can walk, run or fly about. You can alter your camera angles and take pictures (many people do, both still and moving, and galleries abound online). You can converse with other avatars there, and you can teleport to other spaces. Why then has Second Life taken off so successfully where Active Worlds never quite achieved that threshold?¹²

Perhaps it was a question of timing. Computing power and people with ability to use it have become more ubiquitous now. Both Active Worlds, at its inception, and Second Life at the present time, have pushed the limits of typical computer resources, and are thus wholly enjoyable only to those with above-average computers and bandwidth. Both are challenging to use and require competent awareness of how computers work, as well as high tolerance for ambiguity. But ‘normal’ computing power increases more rapidly these days, as do the skills of those behind the keyboard. The culture of computing and digital literacy is more receptive to virtual spaces and more conducive to their potential than was the case ten years ago, and the mindset of both digital immigrants and particularly of digital natives has changed to greater acceptance of immersion in virtual worlds (Prensky, 2001).

Another reason for the success of Second Life is that there is much greater mutual community awareness than there was when Active Worlds appeared on the horizon. The nature of the blogosphere plays to the popularity of Second Life, and promotes the formation of viable communities within virtual spaces. When Active Worlds was developed in the mid-nineteen-nineties the news was spread by e-mail, BBS (bulletin board systems), static webpages, and emergent IM clients like ICQ. Second Life has appeared at a time when people are much more closely interlinked through blogs and various other social networking devices, and news of interest to particular communities tends to spread more rapidly (at the speed of creativity, as Wesley Fryer has entitled his blog). Furthermore, the news now carries with it objects such as video clips that allow people to vicariously experience Second Life without actually being there.

There is also a much better understanding now of the impact that ubiquitous access to computers has had on giving voice to communities in the ‘long tail’ (Anderson, 2004) and Second Life has timed itself to be right in step with this. More importantly, Second Life has become a vehicle for this development, seized by its participants as a means of stimulating interaction among a target spectrum of constituents.

Like-minded people ‘loosely joined’ throughout the blogosphere populate communities which overlap and influence other communities, and these communities disseminate and share a wide range of objects associated with Web 2.0 and social networking, such as open-source scripts and tools supporting interaction in Second Life. For example, a Moodle community has formed, called Sloodle¹³ where you can take ad-

¹²Second Life reached a million users in October 2006, according to <http://blog.secondlife.com/2006/10/18/1000000-residents-happy-crushing-signup-load-sad/>, but see also Clay Shirky’s ‘Story too good to check’ at <http://valleywag.com/tech/second-life/a-story-too-good-to-check-221252.php> where Linden Lab’s figures and means of arriving at them are questioned.

¹³<http://www.sloodle.com>

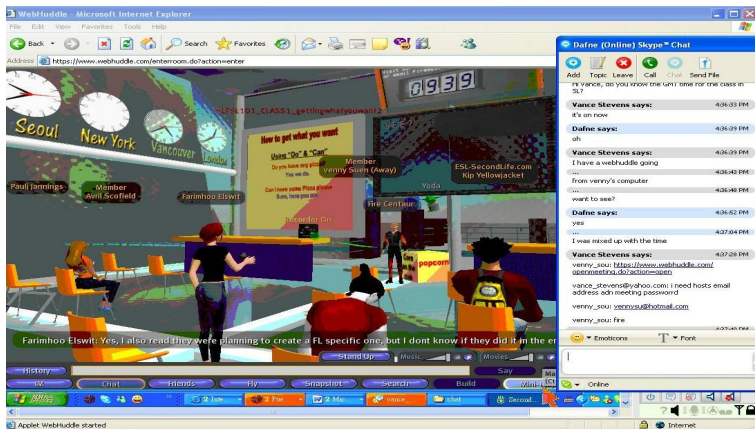


Figure 1: Second Life performance can be degraded by insufficient bandwidth, poor machine resources, and firewalls. In the illustration above, participants are using a thin client called Webhuddle (<https://www.webhuddle.com>) to share the screen of one participant in Second life while interacting with each other in Skype (<http://www.skype.com>).

vantage of various tools in the Sloodle environment and be in Second Life but interact through Moodle. Add-ons, such as the voice clients Ventrilo and Teamspeak are freely downloadable and usable in Second Life. Objects can be found throughout Second Life where developers have linked to digital and multimedia resources available on the open-access Web. Someone has even created a notorious CopyBot that will replicate objects there (much to the consternation of the segment of the community that is not open-source and prompting threats from Linden Lab of expulsion of those using CopyBot).

Second Life has opened doors to creativity and imagination that have been particularly transformative for education. To paraphrase Jeremy Kemp, one of Sloodle's developers, speaking on the Worldbridges Network, EdTechBrainstorm #57, 9 November 2006, the asynchronous objects available in Second Life have much greater potential for transformative impact on educations than the synchronous interaction there.¹⁴

Cory Ondrejka, a developer at Linden Labs, is giving a presentation at the Games + Learning + Society Conference in July 2007 entitled 'Brace for impact: How user creation changes everything.'¹⁵ The abstract touches on how Second Life has less to do with gaming and more to do with peer-to-peer interactivity. Highly flexible virtual worlds are starting to allow content created by one user to be experienced immediately by other users. This 'user-created content' has the capacity to significantly change how games can be used for learning. Technical limitations have traditionally limited the creation of educational games to professional game developers, as they were the group with access to the game-building tools. Second Life is a unique digital world that puts

¹⁴<http://edtechtalk.com/node/739>

¹⁵<http://www.glsconference.org/pop/ondrejka.htm>

the tools in the hands of its residents. Through a scripting language, embedded three-dimensional design tools, an easy-to-use character creation system, and methods for exchanging data with the real world, Second Life allowing highly interactive learner-to-learner and amateur-to-amateur creation and education.

So Second Life isn't just a game?

No, it's not. For one thing, there is no object to it except for whatever goals might be set by individual users. From a constructivist standpoint, that is, or should be, the goal not of a game, but of a programme of learning. Or perhaps the point is that learning might be even more effective if it appears to be a game, or if it is something the learner is intrinsically motivated to do. It is clear that many who are drawn to Second Life are intrinsically motivated to be there.

Second Life is being taken quite seriously by a growing number of successful people and entities firmly rooted in the non-virtual world. It is hard to ignore the serious attention given to this environment by such a wide range of personalities and bona fide institutions (not to mention start-up companies making money off accessories for avatars, and a vast cadre of gamers, which serious Second Lifers avoid by setting up their worlds on islands away from the inconveniences of the mainland. For example, *Reuters* have reported (9 November 2006) that half a million dollars changes hands every day in Second Life.

How seriously Second Life is taken can be deduced from a short list of links with accompanying videos that give you a good idea of what Second Life is like. For example, Susan Vega gave a recent concert in Second Life, resulting in some fascinating artefacts such as a multimedia film clip of how her virtual guitar was constructed,¹⁶ and numerous videos of her performance.¹⁷ Mark Warner, a US presidential hopeful and former governor of Virginia, staged political events, such as a news conference and town hall meeting, in Second Life in September, 2006. This transcript with screenshots can give you a flavour of the event¹⁸ and you can play the *YouTube* video at the governor's website¹⁹

Countless institutions are setting up in Second Life. Giulio Prisco (2006) has an article in the Future Technologies Advisory Group wiki describing several interesting implementations.²⁰ Some others:

- Reuters has a bureau in Second Life and has engaged author Warren Ellis to write a weekly column called 'Second Life Sketches' for the Reuters Second Life News Centre starting January, 2007. In the news blurb, Ellis is quoted as saying 'Second Life is not only the biggest digital art installation in the world, but potentially the most radical shift yet in the way communities are formed online, and possibly also the germ of the next great operating system, ... It's not only a place where people get as strange as they can, but an incubator for the

¹⁶<http://secondlife.com/showcase>

¹⁷http://nwn.blogs.com/nwn/2006/08/nwntv_the_secon.html

¹⁸http://nwn.blogs.com/nwn/2006/08/the_second_life.html

¹⁹<http://www.forwardtogetherblog.com/story/2006/9/15/18268/4612>

²⁰<http://futuretag.net/index.php/Slgp1>

future.’²¹

- The Aho Museum and Gallery being built by the New Media Consortium is going to have a display from the San Francisco Museum of Modern Art.²²
- There is a three-dimensional hospital on Health Info Island where you can meet free online consultants who can help you find resources regarding medical conditions or issues you may be dealing with.²³
- Now you can do your banking online with virtual money. Wells Fargo Bank has set up Stagecoach Island to teach young people the basics of managing their money; see ‘money matters in cybercash game.’²⁴
- In case you need more information, Alliance Library Systems in East Peoria, has won recognition for its Second Life Library 2.0, a virtual library providing real services to Second Life residents²⁵ and Andrea Mercado’s blog ‘LibraryTechnics: A librarian riding the shift.’²⁶

Educational presence in Second Life

Many of the institutions purchasing islands in Second Life are educational ones. Two that provide visual tours of what it is like there are:

- The New Media Consortium (NMC) has a virtual campus on Second Life which you can tour in the video ‘NMC Campus: Seriously Engaging’,²⁷ which provides an overview of Second Life and of the NMC Campus, and how people are building a new way of real work and interaction there. I recently attended a presentation and tour on the NMC campus hosted by a group of media design students who had visited Morocco and then demonstrated what they had learnt about the country and the culture with a ‘build’ in Second Life recreating typical scenes where avatars could stroll.²⁸ I was struck not only by the learning value inherent in the project itself, but also how stimulating it must have been for the students to have attracted so much attention and reaction to their work, as the crowd of avatars gathered at the presentation attested.
- One widely known virtual campus has been created for the Harvard Law School.²⁹ Here you can follow biker and professor at Harvard Law School, Charley Nessen, as he conducts you around CyberOne: Law in the court of public opinion,³⁰ the

²¹<http://secondlife.reuters.com/stories/2006/12/22/warren-ellis-to-write-weekly-sl-column-for-reuters>

²²<http://blogs.electricsheepcompany.com/chris/?p=14>

²³<http://www.rabble.ca/rpn/episode.shtml?x=54785>

²⁴<http://news.bbc.co.uk/2/hi/business/4248074.stm>

²⁵<http://www.infoisland.org>

²⁶http://www.librarytechnics.info/archives/2006/05/kicking_around.html

²⁷<http://www.nmc.org/sl/2006/06/12/seriously-engaging-movie>

²⁸<http://www.nmc.org/sl/>

²⁹<http://cyber.law.harvard.edu/cyberone/videos/CyberOne.mp4>

³⁰<http://www.the-court-of-public-opinion.com>

course mentioned in Carvin (2006) and Lamb (2006). Nesson's daughter Rebecca, also a professor at Harvard, keeps office hours in Second Life. A student participant in that course can be heard in conversation with Jeremy Kemp in the EdTechBrainstorm #57 referred to above.³¹

If you have viewed some of the images and videos at these links and heard the developers describe their experiences 'in world' you would be forgiven for thinking that Second Life could be a creative place for teaching. Among other educators reaching that same conclusion:

- Peter Twinning's Schome³² is not school, not home, but 'Schome', an Open University project leading towards an educational system designed to overcome the problems within current education systems in order to meet the needs of society and individuals in the twenty-first century. Resources available here include Second Life education websites³³ and an annotated list of ideas for educational projects in Second Life.³⁴
- Sarah Robbins,³⁵ aka Intellagirl Tully in Second Life, conducts a creative writing course using Second Life whose syllabus reads like a typical college catalogue, but check out the blogs, for example, 'This is by far one of the funnest things that i have ever done. We have taken school and incorporated video games with it. I feel like we are breaking new barriers for what education can be' (here 'video games' = Second Life). For more information see either Foster (2006) or the website given below.³⁶
- The Global Kids Digital Media Initiative³⁷ has been actively running projects for 13–17 year olds on the Second Life Teen Grid³⁸ examining subjects such as global inequality, the genocide in Darfur, and global warming. It has recently been holding the UNICEF 'World Fit For Children' festival in Second Life, with scavenger hunts, building competitions, and dance parties.
- Anya Ixchel's long post on My Teaching Semester in Second Life: Pitfalls, Challenges and Joys, is an interesting read about how she conducts a New Literacies course in Second Life.³⁹
- You can see kids at play in images posted at Peggy Sheehy's 'Suffern Middle School in Second Life: A running account of the process of the proposal, acquisition, development and integration of a virtual presence for education at Suffern Middle School, Suffern, NY'.⁴⁰ This blog documents uses of Second Life in a K–12 setting and gives illustrative insights into its educational applications there.

³¹<http://edtechtalk.com/node/739>

³²http://schome.open.ac.uk/wikiworks/index.php/Second_Life

³³http://schome.open.ac.uk/wikiworks/index.php/Second_Life_education_websites

³⁴http://schome.open.ac.uk/wikiworks/index.php/Second_Life_Projects

³⁵<http://home.intellagirl.com>

³⁶http://eng104sl.intellagirl.com/index.php?option=com_content&task=view&id=13&Itemid=27

³⁷<http://www.holymeatballs.org>

³⁸<http://teen.secondlife.com>

³⁹http://www.slatenight.com/index.php?option=com_content&task=view&id=107&Itemid=40

⁴⁰<http://rampoislands.blogspot.com>

Many projects in Second Life are geared toward science, technology, design, and enterprise:

- Science – The National Oceanic and Atmospheric Administration and the Earth System Research Laboratory (ESRL) have set up interesting simulations in Second Life, to help people understand phenomena relating to fluid dynamics. According to *Second Life Insider*⁴¹ the NOAA's simulation Meteroa has 'fully interactive educational demonstrations about the ocean and weather. Examples include a sea life submarine ride created by The Magicians, and two different tsunami demos by Aimee Weber Studios and Electric Sheep Company. Other fun stuff includes a demonstration of a real-time temperature map powered by Yahoo, narration by Exploratorium Chief Scientist Paul Doherty, an aeroplane ride into a hurricane, and a melting glacier demonstration'.
- Technology – You can visit the International Spaceflight Museum⁴² on the island in Second Life of Spaceport Alpha, and enjoy a virtual tour courtesy of the Worldbridges Network.⁴³
- Design – Second Life, with its basis in building and creating objects, is an obvious place to experiment with design. As reported in Core77's Design Blog,⁴⁴ 'Philips Design intends to use its presence in Second Life to gain feedback on innovation concepts, engage residents in co-creation and gain a deeper understanding of potential opportunities in this virtual environment. This will allow Philips Design to find new ways of relating to end users. Having such direct feedback can significantly enrich the design process and lead to innovative and surprising end results'.
- Enterprise – Reuters reports that IBM is 'ramping up its push into virtual worlds with an investment of roughly USD10 million over the next 12 months, including an expanded presence within the popular 3D online universe Second Life'. Chairman and Chief Executive Sam Palmisano is holding town meetings there. Why? According to Reuters,

We always ask the question, 'if you knew twenty years ago what you know about the Web today, what would you do differently?' said Sandy Kearney, IBM's director of emerging 3-D Internet and virtual business. The company said it is already holding meetings and conducting development inside virtual worlds with about twenty major clients, including telecommunications and aerospace firms, a petroleum company that wants to use virtual worlds for training and 'a major grocer in the UK' that wants to build a virtual storefront that will allow consumers to buy real-world groceries online.⁴⁵

⁴¹<http://www.secondlifeinsider.com/2006/08/18/noaa-comes-to-second-life>

⁴²<http://slispaceflightmuseum.org/drupal>

⁴³http://worldbridges.net/SL_Spaceflight_Museum_Tour

⁴⁴http://www.core77.com/blog/business/philips_design_joins_second_life_5083.asp

⁴⁵'IBM accelerates push into 3D virtual worlds', 9 November 2006 available from http://today.reuters.com/news/articleinvesting.aspx?view=CN&storyID=2006-11-10T004727Z_01_L09622039_RTRIDST_0_TECH-IBM.XML&rpc=66&type=qcna

There is no shortage of information on educational developments in Second Life. Linden Labs provides 'in world' support at the Second Life website under Community > Education.⁴⁶ SimTeach, providing information and community for educators using MUVE's like Second Life in teaching and learning, has a blog, a wiki, a discussion group, and some sample Second Life videos.⁴⁷ The wiki lists many education projects and resources in Second Life.⁴⁸

If audio is your modality, you can subscribe to Who's on Second? a podcast 'about non-profits and educators jacked into Second Life,'⁴⁹ Podcaster Wayne MacPhail creates a subtly ethereal ambience while conversing with people doing serious and interesting work using Second Life as a base. For example, Nancy Hill, an activist with Code PINK—Women for Peace (Cindy Sheehan, whose son was killed in Iraq, works with this group in real life) and Harry Pence, a Distinguished Teaching Professor of Chemistry at the State University of New York who talks about some of the people he has met online in his own effort to explore the impact of Second Life on online communities of educators. This podcast demonstrates how human Second Life is by engaging the voices underlying the avatars and granting each a soapbox in the podosphere.

Conclusion

The prognosis on Second Life is not universally considered rosy. Charlie O'Donnell raised eyebrows, hackles, and some interesting points with his 27 November 2006 posting of ten reasons to go short on Second Life.⁵⁰ The ten reasons are (excerpted):

1. Second Life 'probably will never be, mobile ... and will not wind up on your cellphones anytime soon'.
2. In 'a short attention span world... small and bitesized. SecondLife can't easily be consumed in small bits. You can't link to an event that already happened, or tag a place, or share it with someone who doesn't have the software'.
3. 'Second Life is a benevolent dictatorship. ... a very small group of people basically dictates what goes and what doesn't in this market. ... a group of people that is not beholden to the residents by law, is a political risk'.
4. 'Second Life is a business. Linden Labs has taken venture capital investment and those firms are going to look for an "exit" at some point over the next four years or so. Maybe Linden Labs will ... have the pressure to grow revenues which may be at odds with the authenticity of the service'.
5. 'Diminishing returns for brand participation... Right now, you can gain a lot of PR buzz by participating in Second Life... probably enough buzz to justify the investment in development for whatever you build to put in there. But, how long will that last?'

⁴⁶<http://secondlife.com/community/education.php>

⁴⁷<http://www.simteach.com>

⁴⁸http://www.simteach.com/wiki/index.php?title=Second_Life_Education_Wiki

⁴⁹<http://www.rabble.ca/rpn/podcast.php?id=woshtml>

⁵⁰http://www.thisisgoingtobebig.com/2006/11/10_reasons_to_g.htmlhtml

6. 'Requires 100% attention. . . You can't casually browse Second Life. . . It's very different than an IM window you can put away in the background when you're doing other things'.
7. 'Lack of context. . . no guidance, no schedule . . . users find themselves lost or overwhelmed'.
8. 'Digital world with an analogue business model . . . but because of their digital nature, Second Life has experienced problems lately with users copying digital items that would otherwise be sold'.
9. 'Reach. No matter how many registered users you have, getting less than 20K simultaneous users online really isn't very much. . . Yes, it's growing, but interestingly, the number of registration is far outpacing the active usage of the site. . . more people are coming to check it out, but they're not sticking around'.
10. Escapism versus Reality. The promise of social networks is that you've got digital self expression going on in unprecedented volume. . . to connect you with real people based on real and authentic things about themselves. . . I thought the blog/Web 2.0/Cluetrain revolution was all about authenticity and living online the way I do in real life. . . my digital world as a reflection of my real interests and real personality? So far, that seems a lot more compelling for people than fantasy. . . otherwise, wouldn't most of the profiles on MySpace be role playing profiles. . . fake people created and maintained by real humans behind them? If I'm a business, I want to make sure I'm connecting in a sincere way with real people as well. . . not sponsoring a fantasy'.

O'Donnell's post has prompted reactions, including Chris Carella's 'Ten Reasons to Go Long on Second Life'⁵¹ which (inexplicably) addressed just one to nine of O'Donnell's points. Regarding the last point, from my own experiences with a community of practice whose members already knew each other in 'real life', if that is a phrase we can use to describe other more familiar yet totally virtual, forms of professional interaction – Second Life has been an enhancement to that, a playground, a crucible for ideas about how people can augment their interaction through constructive, and constructivist, play, work, whatever. In that respect it has supported real productive effort as opposed to its appearance of fantasy.

Second Life promotes a spirit that proclaims that there is much scope in education for experimentation and enjoyment, and the result does not have to look like 'education'. As Stephen Downes also says often in his podcasts, learning should be built into and part of what people do naturally day to day rather than something people are 'kidnapped' into doing within the walls of an isolated institution. If people are drawn to virtual worlds such as Second Life, then educators who are also drawn to those places might be in the best position to intersect with the interests of the target learners already there, or who accept invitations to go there, and help make these experiences educational ones.

⁵¹<http://blogs.electricsheepcompany.com/chris/?p=178>

As Graham Stanley mentions in Language Learning and Web 2.0 technologies for our twenty-first century language learners: Blogs, Wikis, Podcasts, and other emerging technologies,⁵² Second Life might be seen as a prototype for some future form of learning. Whereas that future generation of educational computing might not be Second Life (if it is too commercial or implodes on its own popularity, as O'Donnell suggests) it may be something like Second Life. Lacking a crystal ball, it is hard to say what will happen in a future with so many imponderables, but it is clear that Second Life has caught the imaginations of many who see in the depths of their computer screens how their work can be made more enjoyable, productive, and interactive in the course of encountering others attracted to three-dimensional virtual spaces. One certainty is that Second Life is having an impact and making a difference now, and that it has already altered in interesting and positive ways the shape of upcoming developments in technology appropriately applied in education.

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The use of ICT in primary schools among experienced teachers and teacher trainees: An ally or opponent?

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Abstract

As Brunei is progressing into the twenty-first century, there is a need to prepare pupils to be competent in acquiring and managing information to meet the challenges of globalisation and to increase international competitiveness. There is growing evidence that as a tool, Information and Communication Technology (ICT) can support effective teaching and enhance the development of process skills. However, at present, most teachers in Brunei have still not embraced the use of ICT in their teaching. This paper reports on a study that will investigate experienced science teachers' and teacher trainees' attitudes towards using ICT and factors influencing their use of ICT. Data was obtained through the use of a questionnaire consisting of five categories. The questionnaire was administered to in-service teachers who are now attending a degree programme in the university and to teacher trainees. Some studies report that younger teachers have higher levels of computer literacy and computer anxiety decreased as computer literacy increased. It is also found that younger teachers believe computers in the classroom are essential.

Background

The world is changing rapidly. People are now increasingly concerned with the benefits of all discoveries through the implementation of technology and within society. Transfer of information is accelerated through technological advances. The growth and use of computers and related technology are not limited to workplaces only but also in classrooms. Today's major premise is that the use of Information Communication Technology (ICT) in schools will increase the effectiveness of teaching. Thus, there has been a drastic impact on education system in the use of ICT on global societies. Negara Brunei Darussalam (henceforth called Brunei) is no exception. In 1986, a new subject called computer studies was officially incorporated into the secondary school curriculum and later in 1994, the subject was offered for the first time as an examination subject to Form 5 students. A Department of Communication Technology was then set up in the Ministry of Education to promote the use of ICT in all aspects of education

through ICT incorporation across the curriculum and to oversee the development and progress of the ICT implementation project (Ministry of Education, 2000).

In 2002, a new Upper Primary Science Curriculum was introduced. This new curriculum differed from the previous science curriculum in several ways and among them was chiefly the inclusion of ICT in the syllabus. One of the aims stated in the new curriculum is 'to develop in pupils the basic science process skills (including the use of ICT) and to inculcate positive attitudes and values that are necessary for scientific enquiry and problem solving' (Curriculum Development Department, 2002, p. 4). In the opening ceremony of the first national conference on ICT in education in Brunei, the Deputy Minister of Education continued to emphasize the need to achieve this aim and stressed that 'we should achieve the goal put before us and monitor the quality of teaching and learning activity in the institutions through ICT to produce skillful students to face the challenges of the future' (Laila, 2006a).

In translating the government's aspiration into viable classroom practice; aside from equipping schools with a network multimedia computer laboratory; teachers as the key implementers of the curriculum are offered in-service training on the use of ICT in education (Ministry of Education, 2000). However, teachers need to be convinced of the value of ICT because often they tend to perceive themselves to be technologically incompetent when they first begin to use computers in the classroom (Lee, 2001).

Professor Margaret Cox in her keynote address during the first national conference on ICT in education in Brunei in 2006, however, revealed that despite the importance of ICT in education, there were few teachers who used ICT in their teaching (Laila, 2006b). Additionally, she shared research evidence that there was a lack of expertise among teachers who could use ICT effectively. She claimed that there was not enough support from principals, not enough resources, and the curriculum was poorly understood by teachers. The issues raised by Cox were in fact not different from what Poh and Lim (2004) had reported in 2004. They stated that the success of ICT in science lessons in Brunei was hindered by the lack of ICT facilities, resources and trained teachers. It was also found that some teachers in Brunei were not ready to use ICT in their teaching (Chong, 2001; Norhani, 2002; Sallimah and Leong, 2002). Sallimah (2006) claimed that there was evidence of under-use of computer technology in classrooms, which could indicate that ICT was not used very much in teaching. Sallimah and Albion (2004) earlier reported that factors that would influence science and mathematics teachers' use of ICT in teaching were their attitudes, subjective norms, and behavioural control. In a related study, it was also reported that attitudes and subjective norms significantly influence teachers' intention to implement ICT in classrooms (Sallimah, 2005).

In a study conducted by Princeton Research Associates in 1993 (as cited in Hendarman, 2005), it was found that fifty-nine per cent of teachers under thirty-five believed computers in the classroom were essential while only twenty-nine per cent of teachers over fifty-five shared this belief. In at least two studies (Fletcher and Deeds, 1994; Kotrlik and Smith, 1989), younger teachers were found to have higher levels of computer literacy and computer anxiety decreased as computer literacy increased. These findings were supported by Golden (1997) who claimed that teachers do not use new technology either because they feel uncomfortable with new technology or they lack proper training.

Since teachers are the change agent who play a critical role in the process of teaching and learning (Chin and Hortin, 1994), this paper aims to find out Brunei teachers' perceptions and attitudes towards using ICT in teaching. Most importantly, this paper seeks to document if younger teachers in Brunei have better perceptions and attitudes towards using ICT in teaching. In this paper, 'younger teachers' shall be defined as those who join teacher education institutions immediately on completion of secondary school. Such students will therefore not have had any teaching experience.

Research questions

The focus of this paper was on Bruneian teachers' perception and attitude towards the use of ICT in teaching. In particular, this paper seeks to assess if there is a difference in perceptions and attitudes between experienced teachers and teacher trainees. Three research questions were developed to guide the methodology for this study.

1. What are teachers' perceptions about using ICT in teaching?
2. What are teachers' attitudes about using ICT in teaching?
3. How do teachers perceive the enabling factors that would influence their use of ICT in teaching?

Methodology

Sample

The sample of this study consisted of seventy-one in-service teachers who joined the Bachelor of Education programme (BED Primary Education, henceforth called BED students) and thirty-nine teacher trainees who joined the Bachelor of Arts (BA Primary Education, henceforth called BA students) at the university. The BED students are qualified and experienced, meaning that they had undergone proper teacher training programmes and had a minimum of three years teaching experience. Ninety-seven per cent of the BED students who participated in this study are twenty-six years of age and above. The BA students, on the other hand, are students who joined the university after they completed their A-levels and have not had any teaching experience. Ninety-two per cent of the BA students are below twenty-five years of age. For the purpose of this paper, this group of students (BA students) shall be regarded as younger teachers. There were sixteen males and ninety-four females. Information on their demographic background revealed that ninety-eight per cent of the sample had access to computers at home.

Development of the instruments

The instrument for the study was developed by a group of three Universiti Brunei Darussalam (UBD) faculty members who have expertise in the area of science and mathematics teacher education. The reviewing process led to the refinement of the instrument in two significant respects; grouping the items into five main categories and adapting the Likert-type scale as the style of the questionnaire with the usual five scales. For each item, participants were asked to indicate the extent to which they agreed or disagreed with a given item, with 5 meaning strong agreement and 1 meaning strong

disagreement. All of the items were written positively. The aim was to avoid confusion on the participants' part and to maintain consistency in scoring. Analysis of data gathered in the study yielded a Cronbach alpha reliability of 0.7.

The questionnaire was grouped under five main categories (see Table 1). The number of items varied from one category to another. For example, Category 1 had five items and Category 3 had six items. Because of the different number of items, the minimum and the maximum score for each category was different. Therefore, for Category 1, the minimum total score of five was interpreted as highly negative whilst the maximum total score of twenty-five was considered highly positive, while for Category 3, the minimum and maximum total scores were six and thirty, respectively.

Category	Description	Sample item
1	How would you feel about using ICT in your teaching?	I would feel that teaching using ICT is a good idea.
2	Students' perceptions about using ICT in teaching.	I would certainly like to be able to use ICT in my teaching.
3	Believing that ICT would enhance learning.	I believe that using ICT in my teaching would make my lessons more diverse.
4	Who would have an influence on your using ICT in teaching?	People with whom I work.
5	The opinion of people about them using ICT in teaching.	Principal?

Table 1: Category, description and sample items from the questionnaire.

Results

The results are presented and discussed according to the five categories presented earlier.

RQ 1: What are teachers' perceptions about using ICT in teaching?

This research question was answered by calculating the total mean scores of the BA and BEd students' responses on five items relating to how they would feel about using ICT in their teaching (Category 1) and another five items on their perceptions about using ICT in teaching (Category 2).

A simplified version of the descriptive statistics table on how BA and BEd students' feel about using ICT in teaching (see Table 2) shows that there was no significant differences between the two groups. The mean scores for the five items for BA and BEd students was 4.12 and 4.25 respectively. This result seems to indicate that both BA and BEd students would feel positive about using ICT in their future teaching.

The findings on students' perceptions about using ICT in teaching (see Table 3) broadly supported the result described earlier on how they would feel about using ICT in their teaching. The total mean scores were 3.86 and 3.94 for the BA and BEd students respectively. The value for two-tail significance is more than 0.05 which indicates

	Programme at UBD	N	Mean	Standard deviation	Significance (2-tailed)	Mean difference
How would you feel about using ICT in your teaching?	BA	39	4.12	0.58	0.58	-0.06
	BEd	71	4.25	0.61		

Table 2: Descriptive statistical data of students by programme on how they feel about using ICT in teaching.

that there was no significant difference between the two groups for this category. This shows that both the BA and BEd students have positive perceptions about using ICT in teaching.

	Programme at UBD	N	Mean	Standard deviation	Significance (2-tailed)	Mean difference
Students' perceptions about using ICT in teaching	BA	39	3.86	0.44	0.31	-0.08
	BEd	71	3.94	0.41		

Table 3: Descriptive statistical data on students' perception about using ICT in teaching.

There was virtually no significant development of perception between the two groups of students.

RQ 2: What are teachers' attitudes about using ICT in teaching?

To answer this question, the BA and BEd students' responses to Category 3 were analysed. This category consisted of six positive items about using ICT in teaching. The students' total mean for each item was calculated (see Table 4).

The descriptive table on students' performance on each of the items in Category 3 (see Table 4) shows that significant differences exist among the students on three items. The items were: (i) I believe that using ICT would improve the presentations of teaching materials, (ii) I believe that using ICT would make lessons more diverse, and (iii) I believe that using ICT would develop pupils' learning skills.

The mean scores for BA and BEd students on item 'I believe that using ICT would improve the presentations of teaching materials' were 4.15 and 4.38 respectively. For item 'I believe that using ICT would make lessons more diverse', the mean scores for BA and BEd students were 4.10 and 4.39 respectively. The BA and BEd students' mean scores on item 'I believe that using ICT would develop pupils' learning skills' were 4.00 and 4.30 respectively. For all the three items, it was found that the mean scores for the BEd students were higher than the BA students. The results seemed to indicate that, even though significant differences did not occur in all items, the BEd students have better attitudes about using ICT in teaching than the BA students.

	Programme at UBD	N	Mean	Standard deviation	Significance (2-tailed)	Mean difference
Makes lessons more interesting.	BA	39	4.33	0.53	0.41	-0.79
	BEd	71	4.36	0.68		
Improves the presentations of teaching materials.	BA	39	4.15	0.48	0.03*	-0.22
	BEd	71	4.38	0.57		
Makes lessons more diverse.	BA	39	4.10	0.55	0.01*	-0.29
	BEd	71	4.39	0.57		
Makes lessons more motivating.	BA	39	4.28	0.60	0.39	-0.09
	BEd	71	4.38	0.57		
Help pupils understand lessons quicker.	BA	39	4.00	0.65	0.26	-0.15
	BEd	71	4.15	0.77		
Develop pupils'. learning skills	BA	39	4.00	0.65	0.02*	-0.31
	BEd	71	4.30	0.65		

$p < 0.05$

Table 4: Descriptive statistical data on students' beliefs about using ICT in teaching.

RQ 3: How do teachers perceive about the enabling factors that would influence their use of ICT in teaching?

The data that addressed this research question was derived from the analysis of the BA and BEd students' responses to Categories 4 and 5.

Analysis of the research data by programme on persons who influence the BA and BEd students to use ICT in teaching (Category 4) yielded the results shown in Table 5.

The results of this part of the questionnaire indicated that the mean scores for both BA and BEd students was between 3.56 and 4.27 with no significant difference ($p > 0.05$) between the two groups of students in all of the items. It is interesting to note, however, that the mean scores for both the BA and BEd students on items 'people whom I would meet socially' and 'computer societies' were between 3 and 4. A score of 3 was interpreted as 'unsure', while 4 was interpreted as 'agree'. The results thus seemed to indicate that the BA and BEd students were not sure if people whom they (the students) would meet socially and the computer societies would influence them to use ICT in teaching. The mean scores for item 'people with whom I would work' for both the BA and BEd students were more than 4 (4.11 and 4.27 respectively) which indicated a strong agreement to the item. This result suggests that the people with whom they would work might influence both the BA and BEd students to use ICT in teaching. Table 5 also shows that the BA students' mean score (4.03) for item 'people who are important to me' was higher than the BEd students (3.96). For item 'educational researcher', the BEd students' mean score (4.14) was shown to be higher than the BA

	Programme at UBD	N	Mean	Standard deviation	Significance (2-tailed)	Mean difference
People with whom I would work.	BA	39	4.11	0.72	0.14	-0.16
	BEd	71	4.27	0.44		
People with whom I would meet socially.	BA	39	3.80	0.61	0.10	0.23
	BEd	71	3.56	0.84		
People who are important to me.	BA	39	4.03	0.67	0.63	0.68
	BEd	71	3.96	0.74		
Educational researchers.	BA	39	3.92	0.66	0.10	0.22
	BEd	71	4.14	0.66		
Computer societies.	BA	39	3.97	0.71	0.91	0.02
	BEd	71	3.96	0.74		

Table 5: Descriptive statistical data on students' beliefs about using ICT in teaching.

students (3.92). Even though the difference in the mean scores between the BA and BEd students were not educationally significant, these results could suggest that while the BA students were not sure if the educational researchers could influence them to use ICT in teaching, the BEd students thought that the educational researchers could influence them.

Category 5 is seeking the BA and BEd students' responses about the influence of the principal, colleagues, head of department, parents, pupils and the curriculum department in making responders using ICT in teaching. The BA and BEd students were required to indicate their perceptions by ticking the columns identified as 'should not use', 'use if preferred', 'unsure', 'use when required' and 'must use'. The score for 'should not use' is 1 and 'must use' is 5. When the BA and BEd students' responses in all items in Category 5 were analysed, it was found that there was no significant difference between the two groups (see Table 6). Further analysis of the data, however, revealed that the mean scores for items 'principal', 'colleagues' and 'parents' for both the BA and BEd students was between 3 (unsure) and 4 (use when required). The results might not be educationally significant, however, this seemed to indicate that the BA and BEd students felt that the principal, colleagues, and parents would not have an impact on their decision to use ICT in teaching. Interestingly, for the item on 'students' both the BA and BEd students' mean scores were above 4, with 4.05 and 4.21 respectively. This finding could also indicate that other students might influence the BA and BEd students to decide on using ICT in teaching.

There is another feature of this data that is worthy of comment. Even though there was no significant difference between the two groups of students on items 'Head of department' and 'The curriculum department', the mean scores for the BEd students

	Programme at UBD	N	Mean	Standard deviation	Significance (2-tailed)	Mean difference
Principal	BA	39	3.64	1.01	0.17	-0.27
	BEd	71	3.92	0.98		
Colleagues	BA	39	3.64	1.01	0.36	-0.17
	BEd	71	3.82	0.85		
Head of Department	BA	39	3.79	0.89	0.55	-0.30
	BEd	71	4.10	0.72		
Parents	BA	39	3.41	0.91	0.87	-0.03
	BEd	71	3.44	0.77		
Students	BA	39	4.05	0.92	0.34	-0.16
	BEd	71	4.21	0.81		
The Curriculum Department	BA	39	3.92	0.77	0.38	-0.14
	BEd	71	4.07	0.88		

Table 6: Descriptive statistical data on who would make the students use ICT in teaching.

were more than 4 (4.10 and 4.07 respectively) which indicate a strong agreement to the items. The BA students' mean scores for these items were only 3.79 and 3.92 respectively. The higher mean scores for these items for the BEd students could indicate that the Head of Department and the Curriculum Department could make them decide to use ICT in teaching. The BA students, on the other hand, were found to be not very sure if the Head of Department and the Curriculum Department could make them decide to use ICT in teaching. A possible explanation to this is that the BEd students had already been in schools compared to the BA students.

Discussion and conclusions

The analysis of the results presented in this paper suggest that even though no general correlation between different programmes and more positive perceptions towards the use of ICT in teaching was observed, the pathway is still worthy of comment. There is evidence in this study that as far as attitudes are concerned, Brunei experienced teachers (the BEd students) are more positive in using ICT in teaching than the younger teachers (BA students). It is interesting to note that the finding does not support the previous research that shows younger teachers have higher levels of computer literacy (Fletcher and Deeds, 1994; Kotlik and Smith, 1989). There are a number of factors that may have influenced this unexpected trend in the young teachers' attitudes. First, this scenario may have been caused by the lack of teaching experience among young teachers. The experienced teachers in this study are shown to believe that using ICT would improve the presentation of teaching materials, make their lessons more diverse

and develop students' learning skills. It is expected that without teaching experience, the young teachers would not have a real 'taste' of using ICT in teaching. Secondly, it is possible that the young teachers may not have been exposed to the use of ICT in teaching while they were at university. Without enough exposure, the young teachers would not be convinced of the benefits of using ICT in teaching.

The results also demonstrated the value of certain groups of people in influencing the experienced and young teachers to use ICT in teaching. The young teachers were found to be not very affected by the Head of Department and the Curriculum Department when compared to the experienced teachers. Again, there is no better rationale to explain this other than having prior teaching experience. The young teachers may not be able to anticipate the existence of the causal relationship between the power of people around them and using ICT in teaching.

While the findings of this study only reflect a snapshot of the current educational landscape in Brunei, it would be unjust to assume that young teachers will continue to regress. Most importantly, it must be recognised that some effort has to be taken to ensure the active encouragement of young teachers in using ICT in teaching, these include the teacher training programmes at the university level. Young teachers need to be exposed to the use of ICT in the classroom. One possible way forward is to provide more opportunities for these young teachers or teacher trainees to use ICT in teacher training programmes.

If the recommendation is implemented, it is not impossible that as far as the use of ICT in primary schools is concerned, the experienced teachers and teacher trainees will remain allies!

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Problems in the computer laboratory: An effective method of monitoring student activities and delivering multimedia content

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Abstract

In traditional computer laboratories, the teacher very often needs to leave their desk in order to provide guidance to students who may need additional assistance. But teachers do not have the flexibility to use remote control function and assist students at their own computers. Even if the teachers' use a projector as a teaching tool, students who sit farther away from the projector may have trouble in viewing the content. Moreover, teachers will not be able to allow a student to demonstrate the operational procedures throughout the class. In order for teachers to keep track of students' progress in traditional computer laboratories, teachers need to approach the students to observe their status which is impossible from their own computer via a network. Besides this, some students may engage themselves in misusing the resources and time by playing game-like activities. These issues reveal that traditional computer laboratories are not capable of providing the necessary teaching–learning environment that computer laboratories can offer. *LabCommander*, a software tool, is able to solve all the problems existing in the traditional computer laboratories by making full use of the resources and monitoring the student activities. In this article we discuss ways to improve the teaching–learning process and to avoid the above problems in the computer laboratory by implementing *LabCommander*.

Introduction

In traditional computer laboratories there is no flexible way of managing the students at the computer including monitoring their computer activities in the computer monitor, or broadcast some lectures or teachers or multimedia files onto each one of them on their monitor. Nowadays, information and communication technologies are increasingly utilised by higher education institutions for developing course material, delivering content and sharing content, communication between learners, teachers and the outside world, creation and delivery of presentations and lectures, academic research,

administrative support and student enrolment. In this series, this article analyses the existing problems in the computer laboratory and provides an effective solution to ridding ourselves from such problems.

Problems in computer laboratories

In traditional computer laboratories, the teacher very often needs to leave their desk in order to provide guidance to students who need additional assistance or because they do not have the flexibility to use remotely the control function and assist students at their own computers. Even if the teachers use a projector as a teaching tool, students who sit farther away from the projector may have trouble in viewing the content.

Moreover, teachers are not able to monitor student's activity or allow a student to demonstrate the work to the whole class in real time. In order for teachers to keep track of students' progress in traditional computer laboratories, teachers need to approach the students to observe their status which is impossible from their own computer via network. In some laboratories, students need to gather together into small groups for discussion work or other related activities. Students do not have the flexibility to fully make use of the network and computer technologies available to perform group discussions. At the same time, these facilities should not allow the students to misuse the resources and time by engaging themselves in playing game-like activities. These points reveal that the traditional computer labs are not capable of providing the necessary teaching-learning environment that computer laboratories can offer.

LabCommander: An ICT tool for teaching-learning

LabCommander (LabCommander, 2006) is a network-based teaching software designed to improve teaching environments in computer labs. This software has powerful teaching tools that allow the teacher to maintain full control of students' progress. Additionally, LabCommander increases the quality of teacher-student interactions, and provides convenient computer laboratory maintenance.

LabCommander consists of the master program and the student program. The Master program controls all actions in the laboratory. It is installed on the teacher's computers for the teacher, laboratory teachers, and enterprise management to carry teachers to students. The Student program is installed on the computers for the learners, such as students, members in the training lab, or employees in an enterprise. LabCommander forms a teaching environment, where a master computer demonstrates and gives teachers to the student computers via network.

Features of student computer

After the student program is installed, a LabCommander icon will appear at the bottom right corner of the screen. If the student computer is connected to the teacher's computer, the icon will appear blue or turn to grey if not connected.

The connection between student computer and the teacher computer is established automatically and the student program starts listening to the teacher computer after startup. The electronic check-in feature allows the students to check in electronically by entering their name and ID which can be used by the teachers for keeping track of students who attend class. The teacher will also be able to read the connection status of

every computer on the network using this feature. Along with this the students have the option to use an 'electronic hand-raising' function to get a teacher's attention when they have questions or need assistance. The students can right click on the LabCommander icon and select 'hand-raising', or press scroll lock, the 'student icon' will then appear with a hand sign on the main interface of the teacher computer or if the student wants to talk to the teacher they can right click on the icon and choose 'remote message' from the pop-up menu to start message dialogues with the teacher. These features provides interactive learning environments in the computer labs.

Features of teacher computer

Security: The teacher program is password protected to ensure security. Along with the password it asks for the channel mode in which the teacher needs to log in.

Channel mode: The channel mode is used to separate the class. Let us consider the situation where a university or institution has four computer laboratories. Each laboratory has thirty computers and all the labs are connected together to the same network. As all the computers belong to the same network, the teacher program can see all the student computers irrespective of the lab from which the students has logged in. To avoid this situation it is required to set different channel modes for each laboratory.

Main interface for teacher program: The image in Figure 1 is the interface that appears on the teacher computer. The image is marked into different areas and description to each area is given below.

1. *Title bar.* Shows the product name, version number, and functions of minimising/closing the program and help information.
2. *Class model area.* Displays all the 'student icons'. Teachers can identify the status of the students. Students who are all online will be shown in blue where as offline students will be indicated as grey.
3. *Information area.* Displays the current time, the number of students online, and the total number of students in class.
4. *Audio setting area.* Teachers can adjust the sound quality and set the audio equipment.
5. *Remote message area.* Displays the history of remote message.
6. *Message input area.* Where the teacher enters the remote messages.
7. *Function button area.* 'Broadcast', 'Net Movie', 'Monitor', 'Screen playback', 'Student demo', 'File distribution', 'Silence'.

Operation

To execute a command to selected students, teachers can select the 'student icon' in the 'class model' area, and click the 'function' button they wish to execute. If no Student Icons are selected, the system will automatically apply the command to the entire class. Teachers may also execute a command by right clicking onto the 'Class Model' and selecting the function from the pop-up menu. The command is available when its 'Function' button is in colour. If the button appears grey, it indicates the function is not



Figure 1: The main interface the teacher is presented with in LabCommander.

available for the situation. The 'Function' button will appear pressed when the function is in use. During operation, teachers can press the 'Function' button that is in use again to terminate the command. Teachers may also execute or stop the functions with 'Hotkeys' which can be customised.

How to broadcast movie files?

If you wish to broadcast movie files, make sure the movie is in MPEG1 or DAT format and configure the following settings (i) in 'advance setting' under 'system setting', set the 'broadcast and record efficiency' as 'high', (ii) in 'advance setting' under 'remote setting', set the 'network compensation' as 'for high performance network', and (iii) from Windows start menu > program file > HOYAR LabCommander > video > accelerate setting program, a prompt box will appear. Select 'disable DCI/DirectDraw video setting program', and click 'OK'.

Electronic pointer

'Electronic pointer' is an assisting tool to highlight and add notes to important information during 'broadcast' or 'screen recording'. When you start 'electronic pointer', the pointer toolbar will appear, and you may use the tools in the toolbar to mark on the teacher screen directly. When you hide or close the Pointer toolbar, the marked image will be closed. You may then continue your normal operation.

Voice broadcast

'Voice Broadcast' transmits sounds from the microphone, or other audio input devices, from the teacher computer to the student computers. Click on 'Voice Broadcast' to start this function.

Private chat

Teachers may select any online students to begin 'private chat'. Only the teacher and the selected students will be able to talk to each other when using this function. Content in the conversation will not be broadcasted to the rest of the class. Click on the 'student icon' whom you wish to speak with, and click 'private chat'.

Monitor

Teachers may select student computers to observe their progress. The default 'monitor' setting applies to the entire class and teachers can monitor up to sixteen students at once. You can change the 'monitor' setting in 'display array' under 'system setting', to adjust the number of student screens being monitored at once. You may also set the rotation time in 'switch interval' and the 'settle time' under 'system setting'.

Screen record and play back

'Screen Record' function allows teachers to record the computer operation and sound as a video file for the purpose of lesson preparation and session review. Teachers can replay and broadcast the recorded clip to the entire class with the 'screen playback' function.

Silence

The 'Silence' function helps teachers to catch students' attention by showing a black screen on Student computers and restricts students from using their computers. 'Silence' mode can be applied to the entire class or to individual student.

Remote command

Teachers may remotely start, restart, shutdown or even execute the program. All the remotely executable commands are grouped in this heading.

Summary

After we used LabCommander in the computer laboratory we found it was easy to use interactive software for the teaching and learning process. It allows us to demonstrate, monitor and interact with the students to achieve a comprehensive course. As it supports a wide range of Windows operating systems, from Windows 9X to Windows XP, and the hardware requirements are already available, it provides an excellent platform for eradicating many of the typical problems found in the computer laboratory.

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Pre-service student thinking on using Information and Communication Technology in teaching

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Abstract

“ICT across the curriculum” is a national policy in Brunei for promoting Information and Communication Technology (ICT) integration and use in school teaching and learning. Several ICT workshops and seminars have been organised and implemented towards achieving this goal. This study explored the thinking of some 200 pre-service students (student-teachers) taking a Diploma in Primary Education on the use of ICT in their teaching once they become qualified teachers. Though the student-teachers had no practice teaching experience at the time of the study, except for peer teaching and classroom observations, most of them could express their ideal views on the positive use of ICT in their future teaching. The study also explored whether there were differences in their thinking between Year 1, Year 2 and Year 3 students. This is because compared to Year 1 and Year 2 students, Year 3 students have been more exposed to the use of ICT in their lectures and they had learnt a lot about the benefits of using ICT in the teaching and learning processes.

Introduction

Today computers are pervasive in the workplace, in the classroom, and in the home. Advances in Information and Communication Technology (ICT) and the accelerated transfer of information, together with related knowledge, skills, and abilities, are of great importance in an information society. Using computers and computer-based learning systems in education including primary education is seen as a major intervention to enhance and accelerate learning. Dede (1997) states that new technology promises a rich education experience. Many other studies like Goldberg (1996) and Day, Raven and Newman (1998) support this opinion. They believe that pupils who were taught using both traditional methods and the Internet performed better than other groups who were taught using either the Internet or traditional methods alone. Ganguli (1992) found that in computer-assisted instruction (CAI) when used in mathematics instruction the test group experienced higher enjoyment, greater motivation, and better understanding of

the concepts in the course. It is obvious that improved and accelerated learning can result from using ICT in instruction.

Analysis of previous research and theories about motivation and attitudes and behaviour has shown that a range of factors can contribute to a teacher's motivation to use ICT. These include their attitudes to ICT, their beliefs in the value of ICT for teaching and learning, and their perceptions of whether or not they can use it themselves and use it effectively in their teaching. Motivational factors include making lessons more interesting and fun, contributing to pupils' learning, improving the presentation of materials and making the lessons more diverse. In Brunei Darussalam, the Ministry of Education has urged primary and secondary schools to implement and integrate technology across its national curriculum. Significant funds were approved by the government in 2000 to upgrade the facilities in computer laboratories in all primary and secondary government schools in Brunei Darussalam. This noble move has brought a need for all schools to fully participate in realising the e-Brunei vision and mission of the government. Susilawati and Kyeleve (2006) noted that desirable attitudes and adequate resources are necessary for teachers to develop suitable and interesting teaching strategies that include attractive and interesting classroom activities. Thus, emerging concerns are not only how to best equip teachers with ICT knowledge and skills but also to ascertain that those teachers possess desirable attitudes so that they will willingly integrate ICT in their teaching as well as develop a culture of ICT use in their students. Therefore, the challenge not only rests with school principals and teachers to ensure that technology is integrated in all school subjects but with student-teachers, who will be teachers together with the principals and other experienced teachers need to have a favourable conception on the use of ICT in their future teaching. This is because for efficient implementation and integration of technology in schools, teachers have to ensure the translation of the government's aspirations into viable classroom practice by integrating technology in their teaching (Sallimah, 2005). The major premise is that ICT use in schools will increase the effectiveness of teaching and improve pupil learning.

Teachers' attitudes and beliefs play an important role in determining their classroom practice, particularly in their intention or decision to use ICT in teaching. Phillips, Bailey, Fisher and Harrison (1999) reported that teachers expressed positive attitudes towards the implementation of computer use in the classroom and the curriculum and were motivated to develop themselves in order to be ready to use computers. In addition, a teacher's decision whether or not to use ICT depends on whether or not they have a positive attitude towards the use of ICT with respect to the content of their subject matter. Case studies on the role of teachers' attitude about the use of ICT show that teachers only adopt the new media if they can use them and depends very much on the teacher's existing attitude and practices (Veen, 1993).

What underpins this study is the pre-service teachers' (henceforth called student-teachers) thinking regarding the future use of ICT in their teaching in Brunei primary schools and the positive impact they can perceive ICT can contribute in the teaching process. These student-teachers currently have no practical experience in using ICT in their teaching. However, as students who have undergone the same educational system, they have had some experience in using ICT in their studies, especially during the later years before they joined the Sultan Hassanali Bolkiah Institute of Education. In addition, during their three years training at the institute, they have been introduced to

the use of ICT in different courses they are taking and they are encouraged to look for materials and information related to their courses and assignments such as when they are doing their class presentations and peer-teaching using ICT. A preliminary study done by Sallimah and Albion (2002) on Bruneian science teachers' state of readiness in terms of attitude and competence in using information technology in teaching science showed that most of the teachers have a positive attitude towards ICT though a majority did not have the competency yet to develop their own materials using ICT. Therefore, it would be interesting to examine the views of this cohort of prospective primary school teachers on the use of ICT in their future teaching.

Purpose

The main purpose of this study was to explore student-teachers' general perceptions on the use of ICT in their future teaching and the different factors that permit them to use ICT in their teaching as well as the possibility of those factors being available to and influential to them. This study will provide student-teachers' profiles about the pattern of their thinking about the use of ICT in their future teaching. The implication of the results sought from this study may provide some insights on the relevant and appropriate input to the student-teachers during their training period pertaining to their use of ICT in their future teaching. To investigate the student-teachers' general perception, confidence in and factors that might be achieved or accelerated by their use of ICT in their future teaching, the following research questions were developed to guide the study.

Research questions

1. What are student-teachers' general perceptions about the use of ICT in their future teaching?
2. What factors do the student-teachers think could be achieved or accelerated by their use of ICT in their teaching?
3. How do Year 1, Year 2 and Year 3 student-teachers' perceptions differ in terms of the use of ICT in their future teaching?

Research Methodology

Sample

The sample consisted of 204 student-teachers enrolled in the Diploma in Primary Education programme at the Sultan Hassanali Bolkiah Institute of Education, Universiti Brunei Darussalam. They came from three cohorts; Year 1 enrolled in 2006, Year 2 enrolled in 2005 and Year 3, being the most senior cohort in the programme, enrolled in 2004. Ninety-eight per cent of the sample are between the age of 18–25. Upon registration, these student-teachers undergo a three-year (six semesters) programme and graduate with a Diploma in Primary Education and qualifies them to teach at the primary level of schooling in Brunei. The entry requirement to join this programme is a minimum of five 'O' levels which includes English and Bahasa Melayu (the national language). However, there are student-teachers who come in with higher academic

qualification such as 1 or 2 'A' level passes, but because of their lower grades, they were unable to join the undergraduate programme. Ninety-three and a half per cent of the sample indicated that they have computer access both at home and at the institute. The distribution of sample according to year and gender is shown in Table 1.

	Year 1	Year 2	Year 3	Total
Male	15	26	4	45
Female	69	49	41	159
Total	84	75	45	204

Table 1: Distribution of sample by year and gender.

Instrumentation

The instrument used for this study was adopted from the questionnaire developed by Sallimah (2005). The questionnaire consisted of two parts. Part 1 dealt with the student-teachers' demographic information which included their age group, gender, year of enrollment, highest academic qualification before joining the institute, and their accessibility to computer use both at home and the university. Part 2 consisted of ten questions which dealt with their perceptions of factors that may influence their use of ICT in their teaching, and factors that may be enhanced or achieved by their use of ICT in their teaching. Each question is accompanied by several possible responses ranging from 4 to 12 with each response to be indicated by a five-point Likert scale. The indicators used in the scales vary for some items, depending on the nature of the questions. Some questions require the respondents to choose either: Strongly disagree – Disagree – Unsure – Agree – Strongly agree. Some questions require respondents to choose either: Should not use – Use if preferred – Unsure – Use when required – Must use, while some other questions need the respondents to choose either: Not at all influential – Un-influential – Unsure – Influential – Very influential. There are altogether sixty-three possible responses for the ten questions and the numbers of responses for each question varied from 4 to 11. Therefore, for the purpose of means analysis for each question, a mean of all responses for each question was computed and therefore, for the purpose of reporting, these means are quoted. Analysis of data gathered in the study yielded a Cronbach alpha reliability of 0.92.

Administration of the questionnaire

The questionnaire was administered during Week 13, i.e. the final week of their Semester 1 (2006–2007). Some ten to fifteen minutes were taken to answer the ten questions and this time was taken at the beginning of their lecture period. They were asked to indicate their own responses, i.e. without a discussion with a colleague. For the groups that I did not teach, help was sought from two colleagues but the same procedures were adhered to for consistency purposes.

Data analysis and interpretation

Data obtained from this study was recorded and analysed using SPSS version 10. Comparison of frequencies, means, and one way ANOVA was used to examine Year 1, Year 2 and Year 3 student-teachers' general views, confidence, and the extent to which dif-

ferences exist between their years of study at the institute on their perception towards the use of ICT in their future teaching.

Results

The results of the study are reported by answering the three identified research questions and the data from the study are presented in Table 2.

Items	Year 1 (N =84)		Year 2 (N =75)		Year 3 (N =45)		Total	F-value
	M	SD	M	SD	M	SD		
1. Feeling on the use of ICT in future teaching.	3.96	0.45	4.06	0.70	4.02	0.48	4.01	0.61
2. People who may influence use of ICT.	3.74	0.41	3.79	0.59	3.87	0.49	3.79	0.98
3. Confidence in the success of using ICT in teaching.	3.75	0.37	3.81	0.52	3.82	0.48	3.78	0.80
4. Likelihood of using ICT in future teaching.	4.00	0.44	3.93	0.65	3.94	0.54	3.94	1.49
5. Outcome of using ICT in future teaching.	4.22	0.58	4.20	0.59	4.10	0.77	4.19	0.57
6. Achievement of using ICT in future teaching.	4.13	0.48	4.02	0.60	4.10	0.62	4.09	0.73
7. Opinion of people on using ICT in teaching.	3.76	0.67	3.74	0.67	3.69	0.65	3.74	0.13
8. The extent of influence from the individual people on their use of ICT in teaching.	3.71	0.53	3.82	0.52	3.61	0.63	3.73	2.17
9. The extent to which the individual's opinion influence the use of ICT in teaching.	4.02	0.67	4.02	0.57	4.23	0.48	4.07	2.09
10. Facilities that enable them to teach effectively when using ICT.	3.75	0.42	3.79	0.49	3.79	0.53	3.77	0.19

Table 2: Means, standard deviations and F-value for student-teachers' general perceptions on using ICT in their future teaching by years.

In answering the first research question, generally the student-teachers show a very positive view on the use of ICT in their future teaching. For all ten questions, the means ranged from 3.73 to 4.19. Specifically, questions 1, 3 and 4 measure the student-teachers' general perception on the use of ICT in their future teaching. The results show that the student-teachers feel very positive on using ICT in their future teaching ($M = 4.01$), have a high confidence on the success of using ICT in their future teaching ($M = 3.78$) and they feel that it is very likely that they are going to use ICT in their teaching ($M = 3.94$). Generally, the student-teachers agree that using ICT in teaching is a good idea and appropriate, and with the availability of resources, knowledge, support and skills, they indicated that they would be confident in using ICT effectively in their teaching.

As for the second research question, i.e. factors that the student-teachers think could be achieved or accelerated by their use of ICT in their teaching, is measured by questions 5 and 6 and is shown in Table 2. The results shows that positive outcomes could be achieved if the teaching and learning processes are supported by the use of ICT ($M = 4.19$ and 4.09). They agree that lessons would be more interesting, diverse and more motivating; presentations of teaching materials could be improved; students would understand the lesson quicker and thus their learning skills would be more developed.

In answering the third research question, a comparison of means and a one-way repeated measures ANOVA was conducted to compare if there are differences in Year 1, Year 2 and Year 3 student-teachers' perceptions in terms of the use of ICT in their future teaching. The means, standard deviations and F-value for questions 1 to 10 which measure Year 1, Year 2 and Year 3 student-teachers' perceptions in terms of the use of ICT in their future teaching are also shown in Table 2.

The results show that the F-values show no significant difference between Year 1, Year 2 and Year 3 student-teachers in terms of their general views on the use of ICT in their future teaching. This implies that all groups of students despite their length of years of study at the institute indicate equally positive views on using ICT in their teaching are equally confident in using ICT in their teaching and equally positive on the outcomes that can be achieved in their teaching by using ICT. However, there are two areas which show a decrease in means from Year 1, Year 2 and Year 3 students-teachers i.e. questions 5 and 7. Though the differences are not statistically significant, educationally the differences are noteworthy. While the Year 1 student-teachers show the highest mean (4.22) on their perception on the outcomes that could be achieved in using ICT in their teaching, Year 2 shows 4.20 and Year 3 shows 4.10. Similarly, Year 1 students think highly that the opinion of various people (principal, parents, Head of Departments, etc.) do affect their use of ICT in teaching ($M = 3.76$). However, the mean decreases for Year 2 ($M = 3.74$) and Year 3 ($M = 3.69$). This raises concern as to why the decrease in means could occur. Since no further probing and interviews were conducted during the administration of this study, future study on this area could explore possible reasons for the change in means. However, a possible explanation that could be presented to explain this occurrence is as student-teachers progress to their next year of study, they may have experienced some difficulties in getting access to and using ICT facilities. This could be true as the number of computers and computer laboratories available at the institute is quite limited compared to the number of student-teachers who need to use them. As for the influence of various people on their use of

ICT in teaching, since they might think that ICT is an ‘in thing’ now, the degree of influence from various people is not that important any more but there is always a need to use ICT in teaching.

Discussion and implications

Student-teachers’ general perceptions about the use of ICT (on a five-point Likert-scale) in their future teaching focusing on factors that they believe could be achieved or accelerated by their use of ICT, and their confidence in using ICT their teaching were all positive. Based on the findings of this study, a number of implications have been identified.

Student-teachers’ indication of positive attitude and high confidence should encourage teacher educators to provide and enhance more ICT-related course resources. Since even the Year 1 student-teachers have shown a positive attitude, we need to sustain their interest by providing and promoting more use of ICT in their learning at the institute. Resources and support are two important factors that need to be taken care of by the institute.

The above implication is further supported by the finding of non-significant differences in attitudes in the different years of study. This finding indicated that overall, their years of study at the institute have not changed their positive attitude towards using ICT in teaching. Therefore, their interest in using ICT-related activities and resources needs to be pedagogically more enhanced because reviews on a range of studies on the effects of ICT on students’ motivation, conducted by Cox (1997, 1999) have identified a number of specific motivational aspects, including enhanced commitment to the learning task, enhanced enjoyment and interest, increased self esteem and increases in independence and confidence.

Conclusion

The overall results have shown student-teachers’ indication of positive attitudes and high confidence in using ICT effectively and their positive intention to use ICT in their future teaching. This suggests that more training and skill development in using ICT both in content development and pedagogical practices should be promoted and enhanced. Additional training and the upgrading of skills can only further enhance the factors that influence their future role as primary school teachers and their confidence as qualified teachers.

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Interdisciplinary

Interim report on observations of gender differences in science education

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Abstract

Thirteen and fourteen year olds were given a set of scientific tasks. The amount and type of verbal discussion was recorded. Observations were made of pairs of pupils. Boy-boy, girl-girl and boy-girl groups were analysed. Different types of communication was observed in each group, evidencing a different thought process in operation between boys and girls. Mixed sex groups tended to be dysfunctional.

Background

Current sex discrimination laws require that males and females are to be treated identically. Further, the ‘feminist revolution’ has promoted mixed sex education, and insists that there is to be no difference whatsoever between male and female in any field. The result of this has been policies which have reduced the amount of single-sex education provisions within the UK for example.

Introduction

In this study a standard protocol was designed such that pupils across the ability range could contribute. We were not looking for the ability to solve puzzles, rather the thought processes that pupils utilised. Naturally, it was not possible to study these directly, without the observer affecting the results. Therefore, we studied the verbal interactions between partners within each group. A simple, unobtrusive scoring policy was established, and for many of the pupils, they were completely unaware that they were involved in a study. This was achieved principally by using the regular teacher and support staff for a class as observers.

To test differences in gender, four types of groups of two were selected from a typical set of mixed ability pupils:

- Boy-Boy
- Girl-Girl

- Boy–Girl (assigned at random)
- Boy–Girl (group chosen by partners)

The study was performed by the author and one partner in a range of school types, including; girl's only boarding school, boy's only private (day) school, boy's only comprehensive, girl's only comprehensive, and a mixed comprehensive. This range of schools normalised against school type and social background.

The observer was charged with monitoring all of the communication within a group, but also was required to remain as discrete as possible. This was achieved by the observer sitting close enough to hear, yet still able to observe the group. Secondly, the observations were simplistic, such that a scoring policy was utilised. When a particular type of communication was observed, this resulted in marks on a tally score. Each type of observation studied was effectively an either or statement.

Data set

	S1	S2	S3	S4	S5	Data sets
Boy–Boy	34	36	12	18	22	36
Boy–Girl (friendship)	21	3	4	2	10	26
Boy–Girl (assigned)	11	2	0	1	12	48
Girl–Girl	24	12	2	4	24	24

Table 1: Data set of scores.

S1 (Statement 1) – Pupils make labour division comments.

S2 (Statement 2) – Pupils make predictive comments.

S3 (Statement 3) – Pupils predict data points during collection.

S4 (Statement 4) – Pupils observe a trend and discuss it.

S5 (Statement 5) – Pupils communicate to ensure accuracy.

General observations

These have been listed in no particular order.

1. It was often difficult for the pupils to keep on task, however, this is a general problem with education and is beyond the remit of this study.
2. Many groups showed a remarkable desire to be constantly reassured by the observer that their results were 'correct'. This was particularly noticed with boy–boy groups. They would quite happily take what others told them, rather than work out the answer for themselves. Often this was a problem, in that groups in the study needed to be isolated from the rest of the class as much as possible, without the pupils realising they were being studied.

3. Communication in general was low in boy-girl groups, and almost nil in non-friendship pairs.
4. Girl-girl groups were good at division of labour during the experimental preparation, but boys would seemingly do the work without much discussion.
5. Girls tended to be more careful than boys in the set-up of equipment.
6. Boys were very keen to cheat, and would almost put more effort into getting the correct answer than recording the data correctly.
7. During data collection, the boys were very keen to predict trends within the data, often on the scantiest of grounds.
8. Girls were very reticent about producing theories to explain the experiment whereas boys were very keen to gather some form of understanding about what they had seen.

Specific observations within group types

Boy-Boy

These groups tended to have less labour division discussions. In fact, the majority of the division of labour was performed through direct commands to each other. The experiments were set up with the required precision. During data collection, the pupils regularly predicted their results: often comments such as 'yes, just where it should be'. When challenged about this, they used simple geometrical differences in the series of data to predict the next number. In the prediction discussions, boys tended to say what they thought, in necessary differing wildly between themselves. If the experiment failed to match their predictions, they would think something was wrong, and question their data or look for encouraging results from elsewhere.

Girl-Girl

In girl-girl groups, the experiment seemed to be performed much more sedentarily. They would work in agreement with each other and were prepared to accept each piece of data without pre-judgement. However, once the facts were all collected, they were just as capable as the boys in producing theories which explained their data. Individuals were less likely to offer theories unprompted.

Boy-Girl (friendship groups)

This group was only admitted to the study because several groups refused to work with their allotted partner. However, they were a revelation. Almost without exception, the boy assumed command of the experiment and relegated the girl to the position of his assistant. These groups were productive, but depended heavily upon the mutual acceptance of the social order they established.

Boy-Girl (assigned at random)

Unfortunately, these groups were almost dysfunctional. The amount of cross talk was extremely low and could have been two separate individuals. Both pupils in these groups tried to complete the tasks, but were very reluctant to work as a team. These

groups also showed an extremely high-level of off-task behaviour and many failed to collect sufficient data.

Discussion of data

From this small study, it can be seen that there are clear differences between the approach to problem solving in girls and boys. The difference seems to encompass all social types and is irrespective (statistically) of social group. The data suggests that two distinct gender-specific modes of thought are in operation.

Boys tended to think of a theory and were dynamic as they interacted with the data, finding patterns, using a simple theory to explain these patterns and using logic, and argument to explain. The theory quickly mutated until the best theory was worked out. Often, disagreement between members was quite heated.

Girls tended to be less critical of the data. They looked for patterns, but restricted this action to the data as it had been collected. The approach tended to be methodical and linear. They completed the data and produced a theory which matched what they had gathered.

Mixed groups showed signs of extreme dysfunctionality. If the boy and the girl knew each other, there was stereotypical genderised division of responsibility. Typically the girl would be the subservient member, and her role would be relegated to one of data recorder. Where boy and girl were unknown to each other, an air of an uneasy truce ruled. Each individual was reluctant to communicate at all, and there was no theorising at all.

Conclusions

This study has highlighted what many have long suspected, that regardless of the feminist revolution, males and females have different approaches to problem solving. Each approach, by itself, is a perfectly acceptable and valid scientific technique. However, when these differing approaches are brought together, they fail to result in any synergistic benefits. On the contrary, our observations have demonstrated that these groups are highly dysfunctional. Also, the role of the girls is extremely worrying. If this experience can be assumed to be typical, then girls are being denied opportunities in mixed education, which they can obtain through single-sex education. This also explains why boys perform better in mixed-sex education, they are already acting as the dominant member of a group, and are achieving a better experience than would be expected.

End note

If you are interested in collaborating in this project, the author is willing to provide the exercise sheets and notes on observations. Contact him at: prostron@pi.ac.ae.

Newton and the laws of grammar: Science in the language classroom

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Abstract

‘But I’m not a science teacher’, protests the English language teacher when confronted with the need for the English for Specific Purpose (ESP) curriculum demanded by technical and engineering Foundation programmes throughout the Gulf. These teachers are under pressure by their institutions to provide more scientific communication competences by offering more pertinent language instruction. In this paper we will propose ways that English language teachers can better serve their technical students. To help teachers develop their own lessons, we describe our experiences in the process that have fostered collaboration between the English and Science departments at our institution. In multiple conversations we recognised that we shared many of the same students and, frustrated by many of our students’ lack of understanding of common scientific terminology in the science class and their lack of motivation in the language class, looked for better strategies within our respective curricula, to serve the needs of our students. Perceiving that audio-visual technology might be helpful in cultures with oral learning traditions, we looked to available technology already in our classrooms. We discovered that strategies already developed by ESP researchers and practitioners might help us devise our own materials. Finally, we determined that we would begin with only one lesson at a time and work within our department’s already established curricula.

Introduction

‘But I’m not a science teacher’, protests the English language teacher when confronted with the need for the English for Specific Purpose (ESP) curriculum demanded by technical and engineering Foundation programmes throughout the Gulf. These teachers are under pressure by their institutions to provide more scientific communication competences by offering more pertinent language instruction. This paper proposes ways English language teachers can better serve their engineering and technical students.

Firstly, we begin by explaining what we mean by English for Specific Purposes and how it is currently used within English as a Second Language terminology. We think that Lorenzo Fiorito (2005) defined it best when he wrote that ESP is a method

or approach that concentrates more on language in context than on teaching grammar and language structures. Its focal point, he insists, is that English is not taught as a subject separated from the students' real world (or wishes); instead, it is integrated into a subject matter area important to the learner. By combining subject matter with English language teaching, students become motivated since they are able to apply what they learn in their English classes to their main field of study. The vocabulary and structures that are learnt in a meaningful context reinforces what is taught and can lead to increased motivation.

Here, we will attempt to demonstrate ways that English teachers, most probably trained in Teaching English as a Second Language (ESL) or general English, can incorporate and expand what they are currently doing to include lessons for their students that help them in other subjects they are studying. This might best be accomplished by using available technology. The teacher will also need to look for content specialists in science and mathematics to help in designing appropriate lessons. Finally, we will examine ways in which these content specialists can assist in creating and implementing their content area into the language classroom.

First breakout session

During the conference, participants were asked to form small groups of three or four to determine how technology is currently being used in their own classrooms. Each person was asked to write down three ways that they used technology, share these ways with the group and then select one preferred method that would be reported back to the main group.

Sharing their own experiences in working in an institution preparing students for careers in engineering, we, one of us a science lecturer and the other an English language lecturer, explained the process of how we began to incorporate ESP into our language classes. In multiple conversations, we recognised that we shared many of the same students and both of us, frustrated by many of our students' lack of understanding of common scientific terminology in the science class and their lack of motivation in the language class, looked for better strategies within our respective curricula to better serve the needs of our students. Perceiving that audio-visual technology might be helpful in cultures with oral learning traditions, we looked to available technology in our classrooms or at our institutions. On researching, we discovered strategies already developed by ESP researchers and practitioners might help us devise our own materials. Finally, we determined that we would begin with only one lesson at a time and work within our department's already established curricula.

An inventory of our institution's technology showed that it had available at least one computer networked to the Internet in each classroom, an overhead projector, a video camcorder and movie making software (Microsoft Windows Movie Maker or Apple's i-movie). Thus equipped, we were able to do the following:

1. Asked a student to record an explanation of how to use the graphics calculator¹ that students use in their mathematics and science classes (the English curricu-

¹Each student entering the Foundation Program at The Petroleum Institute receives a Texas Instruments TI-84 graphics calculator.

lum dealt with team organisation and the presenters saw that the graphics calculator had a calendar and organiser that could be downloaded).

2. Divided the students into teams to ask them to make a PowerPoint presentation on what other programs might be downloaded into their graphics calculator that could better help them in their mathematics and science classes (teaching team work and presentation skills are very important in any language classroom).
3. Developed a glossary tied to a core text reading, which defined words in both their common everyday usage and then in their more specific scientific definition (for example, *acceleration* and *work*). Here Moodle,² an open-source software package designed to help educators create effective online courses, is used (The teacher needs to be selective and discriminating in regards to the vocabulary taught).
4. Invited a physics teacher to give a live lecture during an English class. (Listening and note-taking skills are used in the curriculum in relation to ‘simple machines’).
5. Recorded this physics teacher on a camcorder presenting the same lecture.
6. Used Windows Movie Maker, included in the Microsoft Professional Office Suite, to edit and make a short film in wmv format, which can be played with Real Player.
7. Used the created short film as a lesson, preparing vocabulary, note-taking, multiple-choice questions, and true and false questions.
8. Posted the short film on Moodle for students to access outside normal class time. (This involved students using computers for work).
9. Began making and developing e-portfolios for students to show their progress (PowerPoint and graphic skills).
10. Filmed a physics problem to be used in both Physics and English classes (work-in progress with intended use of interactive activities to help students practice analytical skills and science vocabulary in both science and language classes).

Second breakout session

During the conference, participants were asked to form groups and this time each group was encouraged to have at least one science and/or mathematics teacher as a member. They then brainstormed their own ideas about how to add ESP to their own ESL classrooms. Never losing sight of their institutions’ curricula and technology, these teachers were asked to describe a lesson using technology, science and mathematics that could be incorporated into their own classroom. Each group was then asked to share at least one idea where they could use their present curriculum and technology to create an English lesson that utilised science and mathematics in some way.

²An open-source course management system available from: <http://www.moodle.org>

We concluded this session by distributing CDs with samples of our own work and providing participants with membership into a forum on Yahoo to cement what we have learnt and to support teachers in their quest to help students acquire the skills they need to study technology, science and mathematics in the twenty-first century.

Conclusion

In writing this paper we hope to have encouraged readers to reflect on the methods they use in the teaching of English at their institution by brainstorming the introduction of English for Specific Purposes into a few lessons, listing available technology, and showing how the design of a lesson using ESP in the classroom can be begun.

We are committed to exploring better ways to teach Academic English to Arab students in the Gulf and it is our contention that the best way is for teachers sharing similar goals and objectives to begin networking and working together.

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Culture and its effect on student learning

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Abstract

Culture plays an important role in people's lives in general, and students' lives in particular. It enhances or hinders student learning. Numerous authors have written about culture and its effect on students' disposition to learning. Student performance, behaviour and attitudes in the classroom and outside are affected by the students' cultures, values, what they carry with them or what they believe in. It is imperative for teachers in the classrooms and educators working in the education profession not to miss the opportunity to understand and appreciate their students' cultures. Educators need to consider cultural learning differences. Things like respect for time, collaboration and team work, motivation, communication, and intercultural understanding all affect learning. They could either help or hamper a person's learning. Students who have rich, supportive learning cultures would be highly effective learners, while others, whose cultures are not supportive, would not. In this paper, the authors talk about the effect culture has on learning in terms of student characteristics, valuing time, collaboration and team work, motivation, communication and intercultural understanding. They also discuss what educators can do to help learning with different cultural backgrounds. Finally, the authors discuss the results of two surveys, one in ICT classes and one in English. The surveys deal with different cultural aspects that affect students and their classroom learning and performance.

Introduction

Culture plays an important role in people's lives in general, and students' lives in particular. It entails a combination of elements that shape the person or the community. It includes things like knowledge, language, beliefs, education, experience, tradition, values, and religion that make up a community's composition and lifestyle, its way of thinking. Culture is also the concept described as 'the values, attitudes, and patterns of behaviour that are transmitted to all individuals in a particular social environment. Culture moulds the self, prescribes the relationships, and defines and reinforces our thoughts and feelings' (Poole, 2006, p. 5).

Culture plays a significant role in helping students enhance or hinder their learning. Numerous authors have written about culture and its effect on students' dispositions to learning. Student performance, behaviour and attitudes in and outside the classroom are affected by the students' culture, values, what they carry with them and what they believe in.

In this paper, we discuss the effect culture has on learning in terms of student characteristics, valuing time, collaboration and team work, motivation, communication and intercultural understanding. We also highlight what educators can do to help students with different cultural backgrounds to learn. Finally, we discuss the results of a survey that deals with different cultural aspects that affect students and their classroom learning and performance.

The effect of culture on learning

Students are not the same. Each student carries with him or her things that they bring with them from their own cultures. We know from research that 'an individual learner's culture, family background, and socioeconomic level affect his or her learning. The context in which someone grows and develops has an important impact on learning' (Guild, 1998, p. 1). Individual differences also affect the way or what the student is willing to learn (Abu-Rmaileh 2006a, 2006b; Guild 1998).

It is imperative for teachers in the classrooms and educators working in the education profession not to miss the opportunity to understand and appreciate their students' cultures (Bennett, 1986, Scribner, 1996). Educators dealing with students with varied cultural backgrounds need to take into consideration differences in learning because of such varied cultures. Things like respect for time, collaboration and team work, motivation, communication and intercultural understanding all affect learning. They could help students to improve their learning or hamper their efforts. Students who have rich or supportive learning cultures would be highly effective learners. While others, whose cultures are not educationally supportive would not sustain effective learners. Depending on the cultural background the students bring with them, those issues could allow the students to excel in what they are doing. Many cultures, for example, respect deadlines, and for that we find students honouring those deadlines in completing projects. They are not behind in many of things that they do. Thus, they succeed. Other cultures might be highly motivated. They tend to push their children toward achieving better results and attaining the highest educational goals.

In a paper presented at the annual meeting of the American Educational Research Association, Hixon (1991) pointed out that teachers who blend content area knowledge and subject-specific instructional knowledge while having the driving factors of diversity, and the contextual factors on student classroom attainment will increase and advance the opportunity for enhanced educational results for all students. Taking culture into consideration when teaching improves students overall achievement.

Students' characteristics

Like individual differences that affect learning, students are also affected by how they deal with the knowledge that they attain from being at a learning institution. Some students use the information they get in ways different from what it was intended for. Students also differ in 'how they process information and how they think. Some people

are always looking for connections and ways to tie things together. Others are more divergent. One thought, idea, or fact triggers a multitude of new directions. Some people order ideas, information, and experiences in a linear, sequential way, while others organise their thoughts in clusters and random patterns' (Guild, 1998, p. 6).

In addition, there are students who have or exhibit different responses, emotional or mental, to issues that are presented in the classroom. One thing could be perfectly acceptable to some students, but at the same time offensive to others. Students who have mutual trust with other students tend to work with them better than those who mistrust their classmates. They tend to cooperate with the teacher and other classmates in the spirit of accomplishing the required work.

Valuing time

Managing and valuing time in this busy world is a valuable necessity that everyone should know how to control. In today's fast-paced life, one ought to manage time for studies, work, family, and for leisure. Researchers have pointed out that the 'concept of the passage of time, duration of time, and points in time varies among different cultural groups. Both clock time and social time influence family behaviour' (Poole, 2006, p. 7).

Time perception both in and outside of the class are significant indicators as to how students view time and how they utilise it effectively. It is also an issue of how students in different cultures value time and their ability to successfully use that time. For students, one of the major challenging issues that they face is how they manage their time and balance the different courses that they are taking. Students need to balance their time among the many things they do. They need to be able to shuffle their schedules between curricular, extra-curricular and the social activities that they have on campus, in the hostels or at home.

Furthermore, 'one means of understanding how cultural characteristics affect classroom organisation is to examine how the effective use of time is achieved. Time-on-task, otherwise known as "active learning time," is linked to the principle that learning takes time, and the time that students spend in active involvement in academic work is central to successful performance' (Beckum, 1988, p. 18). It is extremely important to keep students working on the task at hand, focusing on the major issues required of their learning without wasting valuable time.

Collaboration and team work

At work or at school, collaboration and team work are essential requirements for a good and successful work environment. LeBaron (2003) points out the important issue that 'culture is always a factor in conflict, whether it plays a central role or influences it subtly and gently. For any conflict that touches us where it matters, where we make meaning and hold our identities, there is always a cultural component' (pp. 2–3).

In addition to that, groups with the prevailing culture are the envy of the less dominant culture. Thus, conflict, contradictions and struggles affect collaboration and team work. Beckum (1988) states that even though cultures 'may share many similar values, they often do not have equal opportunities to assert themselves. . . . school and classroom culture is a domain of competing interests in which dominant and dominated groups make sense of their life circumstances and conditions. It is this conceptualisation of culture that is significant for educators' (p. 4).

Motivation

Student motivation is one of the most important issues that affect student disposition to learning. Culture is one of the main factors that influence student motivation. The background that the students carry with them in terms of language, values, beliefs, traditions, and religion all affect students' motivation. Culture is the source and basis of the students' internal of motivation (Abu-Rmaileh, 2006a, 2006b). Some students are motivated because their culture, including their families and their communities, urge them to learn and perform well in school. Others, whose culture values manual labour, do not see a need for education and do not place a value on it.

Another motivation characteristic that students possess is whether they themselves can motivate others they are working with. Is there enough strength in the students to rally others in the groups they are working with? Before they can do that, they themselves need to be motivated enough to bring everyone around to work together to fulfill the shared goals of the group.

Communication and intercultural understanding

Different cultures communicate differently. In general, 'communication includes all verbal and non-verbal behaviour between people, including things such as vocabulary, grammatical structure, silence, touch, facial expression, eye and body movements and expression of warmth and humour. Miscommunication is a ... subtle problem ... that result[s] from cultural differences in meanings of non-verbal behaviour' (Poole, 2006, p. 7).

Over the years, cultures have changed. It is widely known that 'the development of transportation and communication technologies has linked the world together in ways which make it simple to travel or communicate with people and cultures around the world' (Hauben, 1994).

In the classroom, not understanding cultural issues on the part of the teacher or the students among themselves could create conflicts and misunderstandings. These conflicts could derail the teaching and learning process. They would make the teachers' job more difficult and more challenging. Any misconstrued comments on the part of the teacher or the students could ignite a huge conflict that might divide the classroom and alienate both students and teachers alike.

Students also need to be able to know how to communicate with other students in their group. They need to do their best to be effective listeners and communicators so that they can relate proper information in a way that is not misunderstood, nor misconstrued. They need to be good enough to reach everyone in the group they are working with.

Ways to help students with different cultural backgrounds to learn

There is no magical solution for how to embrace culture in the classroom. Good teachers are those who are adaptable to new teaching situations. They are always working for the students. It is those 'successful teachers [who are] aware of their own and their students' culture, and [are] respectful of both; [plan] for the incorporation of the student's culture into classroom practices; [link] the curriculum to student experience; [maintain] close contact with the students' family and community; and [are] extremely

successful in identifying individual student learning styles and motivational characteristics' (Beckum, 1988, p. 8). One of the teacher's jobs is to make sure that the students are brought together, ensuring that there are no gaps among students by not favouring or making one dominant culture see itself better than the other (Jenkins, Gappa and Pearce, 1983; Sheffield, 1997). Moreover, 'students are all diverse in culture, race, gender, physical, emotional and social needs. The teacher must find the most beneficial way to reach this wide range of student learning styles and create a model in the classroom that represents the cultural diversity of the community. Students benefit from diversity because they are all able to learn a cultural aspect of society from each other' (Huver, 2001, p. 4). For educators to help students in their presence in the classroom and in their learning, they should be able to accommodate the different cultures and the varied individual differences that students bring with them (Hilliard, 1989; Ramirez, 1989). In the following section, some important strategies will be offered to help students adjust to varied classroom cultures.

Get to know your students' backgrounds

One of the first things that teachers should be doing in class is getting to know their students. Teachers need to know what kind of students they have, their backgrounds and some information about them that would help them avoid stereotypes and cultural pitfalls. This is important because teachers can build good relations with their students. Students want their teachers to 'demonstrate caring and genuine concern about them. [As a teacher] you may have more positive experiences with students if you invest some time and energy into becoming informed and more aware of issues affecting students of various backgrounds' (Saunders and Kardia, 2006, pp. 9–10).

A good way to get to know the students is to ask them to write a journal that allows the students to write an autobiography of themselves, where they come from, their backgrounds, number of family members, whether they are married or not, etc. If they feel comfortable to share their stories with other students in class, students can do a five-minute presentation at the beginning of the course that tells about them.

Include all students in the learning process

It is important to have everyone in the classroom be part of the learning process. Regardless of their backgrounds, attitudes, or thinking, all students deserve a chance to be heard. In the classroom, 'when students are speaking to each other, monitor the discussion to make sure that students show consideration and respect. Make sure that all groups are able to participate. Intervene if a person or group of people are trying to dominate the discussion' (Fisher College of Business, 2006, p. 2).

Students should also feel that they are free to voice their ideas and opinions without overshadowing others' opinions. A 'no one left behind policy' should be the norm in any classroom. Everyone has to be on board in the learning process, valuing everyone's comments and responses (Hall and Sandler, 1982).

Treat students as individuals

All students are not the same. Individual differences affect the students' learning process. Each student comes with a set of values that affect their learning. They are also different in age, sex, socio-economic backgrounds, family status and others. Teachers need to respect those individual differences and try and use different tools to help students adjust to the learning environment (Abu-Rmaileh, 2006a, 2006b; Guild, 1998).

Teachers need to know that ‘each of us has some characteristics in common with others of our gender, race, place of origin, and socio-cultural group, but these are outweighed by the many differences among members of any group’ (Davis, 1999). Good teachers tend to devise materials in a way that would allow their students to overcome their individual differences or adapt in a way that would allow them to participate in their learning.

Avoid teaching controversial material

Curriculum and materials studied should not favour one group of people or one culture over another. Controversial material tends to sway students one way or the other. The job of teachers is to bring the students together and not to divide them. There is no need to discuss issues of religion, sex, sexual preferences or politics. The classroom is a neutral place and things like that do not belong there. If the material includes photographs, make sure that those are appropriate and do not include nudity or indecency. As Saunders and Kardia (2006) point out, teachers need to ‘give serious consideration to students’ requests for alternative materials when materials currently used inaccurately represent aspects of students’ social identity groups or cultures’ (p. 11). Teachers should be flexible enough and ready with alternative non-controversial or inappropriate material to use in class.

Do group work and collaborative learning activities

One of the issues that we mentioned earlier is that students with dominant cultures try and over-run students with the less dominant culture or tribe. Because of that, it is sometimes difficult to do cooperative or team work with students. Students tend to want to be in a certain group because they can relate to that group. It is extremely important for teachers to mix groups so that the spirit of collaboration and the spirit of team work are established. Students need to know that they are working in the classroom as a team and not as separate individuals. Teacher supervised problem-based learning, pair work, group projects, and collaborative learning activities should alleviate most of the tension being created by diverse cultures. These activities also help ‘to facilitate student learning, to improve interpersonal relationships among students, to foster responsibility for students’ own learning and the learning of others, etc.’ (Saunders and Kardia, 2006, p. 8).

Carefully word your responses to students’ comments

Many times students challenge teachers in how far they can go with their comments. Careful consideration to how to respond to comments made by students is the most prudent thing that teachers can do to avoid conflict between students and teachers and the students among themselves. Teachers should also be aware that they should not look like they are favouring one student or group of students over another.

In addition to that, when conflicts arise among students, teachers should not take sides or support one student over another. As Saunders and Kardia (2006) point out ‘heated discussions need to be facilitated in a manner that does not result in hostility among class members and a sustained sense of bad feeling in the room. You can avoid these outcomes by encouraging students to tie their feelings and conflicts to the course material and by looking for underlying meanings and principles that might get buried in the process of class conflict’ (p. 13). Students are extremely conscious of how teachers address conflicts and are grateful for the way their teachers resolve those conflicts

without taking sides and without putting students down, respecting each and every one of them.

Survey procedures

Different aspects of culture and how they relate to learning were assessed in a survey (see Appendix) to determine how each item affects student learning. The survey looked at six categories (i) attitude toward time, (ii) collaboration and team work, (iii) students' characteristics, (iv) cultural intelligence, (v) motivation, and (vi) communication. They were labelled A to F, respectively. Each category had four different sub-categories.

Forty-two teachers from the United Arab Emirates University, University's General Requirements Unit (UGRU) filled out the survey. They were asked to fill it out based on their perceptions of how effectively the students used the different items in the survey to help their learning. The teachers who filled out the survey were from UGRU's four programmes, Information and Technology (IT), English, Arabic and Mathematics. Eight teachers were from IT, five from Arabic, twenty-three from English, and six from Mathematics.

The survey asked the teachers to identify themselves as to which programme they belonged. The teachers were asked to rate each item based on its importance in affecting the students' learning. They were asked to rate the items based on importance on a scale from 1 to 9, 1 being not important and 9 being very important. For each topic, there were four related items to rate. The teachers were also given two open-ended questions. The first was 'Do you think that the above [items] positively affect learning? If so, how?,' and the second question was 'Do you think that the above [items] negatively affect learning? If so, how?'

Results

The one-way ANOVA test, using the Tukey variance was used to analyse the data collected. The averages of the six categories' scores and the other categories were compared with a significance level of 0.05. The results showed a significance of 0.048. A box-plot comparing the responses given to the different categories in the survey is shown in Figure 1. It outlines the results, showing some minor outliers in their responses to the different categories in the survey.

Finally, a bar graph displaying the different categories used in the survey is shown in Figure 2. Here the averages of the different categories, showing C–Student characteristics as the least important with an average of 6.2. It also shows A–Attitude toward time and F–Communication being the most important.

Teachers' comments

The teachers were given the chance to reflect on their own ideas by commenting on how positively or negatively the cultural items affect learning. Depending on what the students are doing in their work, it could be negatively or positively affected. For the teachers who said that the positive impact cultural issues had on learning had to do with students respecting each other as individuals and respecting team work. Other teachers said that social skills also affect learning. Whether students are equipped with those

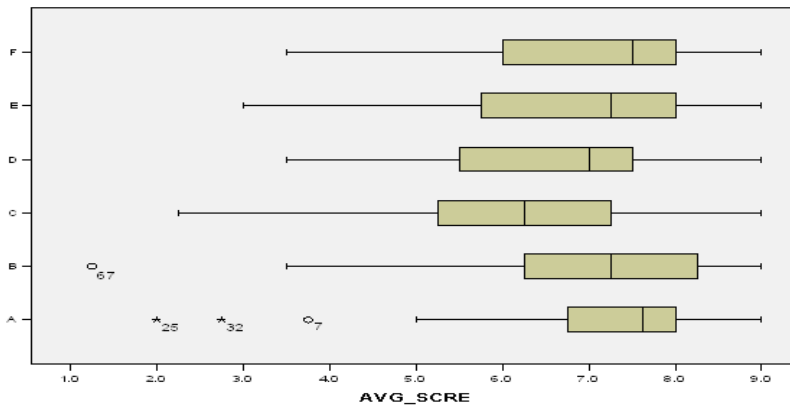


Figure 1: Box-plot for all respondents showing outliers.

skills plays a crucial role in helping them learn. Some teachers talked about the importance of having a good teacher–student relationship in order to facilitate learning. Using time effectively and balancing curricular and extra-curricular activities would help focus student work and would positively affect learning. Other comments were that knowledge sharing and effective communication are essential for learning. Finally, many comments were related to student motivation and how, when students are motivated properly, they would accomplish great results.

As for how the above negatively affect learning, the respondents commented that when the students do not collaborate or communicate with others in their learning, they would be negatively affecting their learning. Also, if the students are not on task and waste time or do not honour deadlines, they would hinder their learning. Another comment had to do with students not utilising the tools that they have at hand. If they are not working properly with what they have, they would lose many of the available learning opportunities. Finally, the most important comments had to do with the fact that when students are not motivated in one way or another, their education and learning process would not be complete.

Survey conclusions

In general, the responses to the items in the survey were close in rating. The teachers in the different programs showed close opinions about their perceptions of how each item is important to the learning process of the students. In order to see a visible difference in responses, one has to go to a 0.1 significance level on a post hoc, multiple comparisons test.

Apparently, teachers from different subject areas agree on the importance of the cultural items in the survey in helping student learning. According to the teachers' comments without those cultural tools, the students would be unable to help themselves and others in their learning.

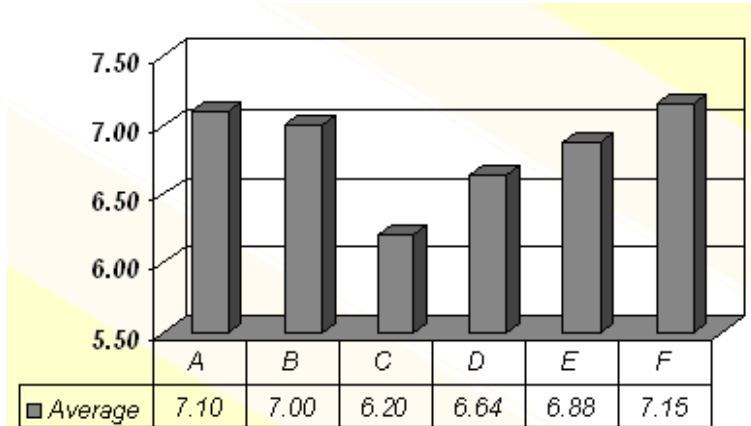


Figure 2: General category averages.

Conclusion

Learning does not take place in a vacuum. Students are inundated and overwhelmed with great number of things that affect their learning. Culture is one of the most important aspects of students' education that affects their learning and their attitudes towards education in general. Culture could enhance or hinder someone's learning style, attitude and behaviour in the classroom. Things like motivation, communication and openness, collaboration and team work, valuing time and others affect students' disposition to learning.

Good teachers are the ones who consider the above issues and use them in a way that would support student learning. Accommodating culture and cultural attitudes in class are another part of the learning and teaching process that teachers should never neglect. Effective educators are the ones who are able to bring all students together to help ease their learning and their classroom experience. Working in groups of mixed cultural backgrounds helps students recognise each other's diversity and willingness to work. Helping students in avoiding the use of controversial material would allow the students to feel safe and secure in the classroom environment.

Based on the expert judgment of surveyed teachers, learning can be enhanced by the cultural attitudes that the students have. One has to be able to use his or her cultural background to improve their attitudes towards learning. Collaboration and communication with others are excellent tools to help advance learning.

Appendix

A survey of different aspects that affect students and their classroom learning and performance

This survey should be filled by one of the following teachers. Check what you teach.

- | | |
|---|--|
| ☐ IT Teacher | ☐ Mathematics Teacher |
| ☐ Arabic Teacher | ☐ English Teacher |

For each item, rate how important is each item below in affecting learning by selecting one of the circled numbers. A rating of 9 equals very important while a rating of 1 equals not important.

A. Attitude toward time

1. Manage time and resources in an effective manner.

1 2 3 3 4 5 6 7 8 9

2. Respect time and value it.

1 2 3 3 4 5 6 7 8 9

3. Understand and adapt to general view of time (schedule and school work versus personal relationship commitments).

1 2 3 3 4 5 6 7 8 9

4. Maintain a balance between curricular, extra-curricular and social life.

1 2 3 3 4 5 6 7 8 9

B. Collaboration and team work

1. Demonstrate a balance between personal and professional roles and responsibilities.

1 2 3 3 4 5 6 7 8 9

2. Work effectively to understand self and others.

1 2 3 3 4 5 6 7 8 9

3. Provide consistent feedback to others regarding group performance.

1 2 3 3 4 5 6 7 8 9

4. Work with others to enhance team commitment and collaboration.

1 2 3 3 4 5 6 7 8 9

C. Students' characteristics

1. Students use department's tools and equipment effectively.

1 2 3 3 4 5 6 7 8 9

2. Students use skills and knowledge acquired at UGRU.

1 2 3 3 4 5 6 7 8 9

3. Students are familiar with other students' backgrounds.

1 2 3 3 4 5 6 7 8 9

4. Student have mutual trust among themselves.

1 2 3 3 4 5 6 7 8 9

D. Cultural intelligence

1. Students show understanding of their shared culture.

1 2 3 3 4 5 6 7 8 9

2. Students' ability to understand other cultural world views.

1 2 3 3 4 5 6 7 8 9

3. Students can recognise the abilities of classmates.

1 2 3 3 4 5 6 7 8 9

4. Students' ability to culturally express themselves effectively.

1 2 3 3 4 5 6 7 8 9

E. Motivation

1. Ability to encourage group members.

1 2 3 3 4 5 6 7 8 9

2. Share goals and visions.

1 2 3 3 4 5 6 7 8 9

3. Provide appropriate assistance to others.

1 2 3 3 4 5 6 7 8 9

4. Use rewards and encouragement to achieve desired results.

1 2 3 3 4 5 6 7 8 9

F. Communication

1. Use active listening and effective feedback skills.

1 2 3 3 4 5 6 7 8 9

2. Understand and use effective relationship strategies to maintain trust within the class.

1 2 3 3 4 5 6 7 8 9

3. Encouraging classmates to use their own leadership, judgment, and decision-making capabilities.

1 2 3 3 4 5 6 7 8 9

4. Talking to everyone and using teamwork to get things done.

❶ ❷ ❸ ❹ ❺ ❻ ❽ ❿

Answer the following questions.

Do you think that the above positively affect learning? If so, how?

Do you think that the above negatively affect learning? If so, how?

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Constructivist-visual mind mapping teaching approach and science students achievement

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Abstract

The aim of this study was to compare the effects of a constructivist-visual mind map approach (CMA) and a traditional teaching approach (TTA) on student achievement. The sample of the study consisted of six classes (140 Form 3 students; 13 to 15 years old) selected from a typical co-educational school in Brunei. Three classes (40 boys and 30 girls) were taught using the TTA and the other three classes (41 boys and 29 girls) using the CMA enriched with PowerPoint presentations. Student achievement was evaluated using an achievement test consisting of sections of multiple-choice, structured questions, and a descriptive question. The mean achievement scores as well as the mean gain in achievement scores of CMA students compared to the TTA were significantly higher on the whole test as well as in the sections of the achievement test. Moreover, there were no gender differences in the mean achievement score for the CMA group, whereas such differences in the traditional group were statistically significant. These results suggest that a CMA approach to teaching was more effective in improving student achievement as well as in minimising gender differences in academic achievement. It is therefore recommended that teachers use this teaching technique to improve students' academic achievement in science.

Introduction

The Brunei Ministry of Education (MOE) is deeply concerned over the existing status of science education because it is linked to the human resource planning needs of the nation (Ahmad-Jumat, 2000; Sharifah-Maimuna, 1999). At present, there are many expatriates working in Brunei Darussalam especially in science related fields. According to Ahmad-Jumat there is a tendency of students to be over represented in the arts stream and under represented in the science stream. There are not many students who are studying science subjects at the institutions of higher education because their levels of achievement at school level in these subjects are not acceptable. The implication is that the existing system will be unable to cope with the demand and supply of local needs, and many of the higher level professional jobs in science related fields will still be held by foreigners even in 2011 (Sharifah-Maimuna, 1999).

In Brunei, the classroom teaching style used is traditional (Monaliza, 2001) despite it being demonstrated to be less effective than constructivist teaching. Traditional teaching appears to be responsible for lower than acceptable student achievement and hence they cannot continue their studies at institutions of higher education. It was therefore decided to try a different classroom teaching approach that involved constructivist teaching enriched with a mind mapping technique and to compare its effectiveness in improving students' achievement to the traditional teaching approach.

Literature review

There are many studies in the literature that are consistent with the learning theory known as constructivism (Ausubel, 1963, 1968; Ausubel, Novak and Hanesian, 1978; Fisher, 2004; von Glaserfeld, 1987; McComas, 1997; Wandersee, Mintzes and Novak, 1994). These studies highlight that the constructivist theory is more closely associated with the way we learn new knowledge. Hence, it is associated with improvement in achievement of students taught using this philosophy. Research also indicates that as teachers make transitions from a behaviourist to constructivist point of reference, their thoughts, behaviours, and classroom practices change totally (Lorsbach and Tobin, 1997). It is also known that exemplary science teachers have incorporated the constructivist epistemology approach in their classroom practices (Tobin and Fraser, 1990). In summary, the research shows that student achievement can be improved by incorporating constructivist teaching in the classroom. However, it is believed that gain in achievement can be further optimised by enriching constructivist teaching with technology and mind-mapping techniques.

There are studies that show little or no effect of technology use on student achievement (Jabaidah, 2002; Mohd-Zamri, 2004; Wang, Wang and Ye, 2002). In these studies, the authors mostly incorporated technology into traditional teaching. For example, Mohd-Zamri replaced overhead projector slides with PowerPoint presentations. Despite the above, these studies indicate an improvement in student perceptions of science learning. In contrast, it has been reported that the use of technology in an interactive format provides students with appealing and attractive learning environments (Barnea and Dori, 1999; Divaharan and Wong, 2003; Kumar and Helgeson, 2000; Shute and Gawlick-Grendell, 1994). For example, Divaharan and Wong (2003) reported that PowerPoint presentations provide a useful, shared focus for whole-class teaching, and a clear framework for learning. These studies suggest the use of technology improves the learning environment which may help optimise student learning within a constructivist classroom.

Neurocognitive science reports empirical evidence to support that visual-mental images are generated by both right and left hemispheres using activated early visual cortices (Damasio, Grabowski, Damasio, Tranel, Boles-Pontes, Watkins and Hichwa, 1993; Farah, 1989; Kosslyn, Alpert, Thompson, Maljkovic, Weise, Chabris, Hamilton, Rauch and Buanomman, 1993; Kosslyn, Thompson, Kim, and Alpert, 1995; Le Bihan, Turner, Zeffiro, Cuenod, Jexard and Bonnerot, 1993). When an individual seeks to recall an experience from memory, all those multiple constructs (of colour, shape, form, motion, even the cortices where the nouns and verbs are located) that were used to describe the original events and objects, are reactivated just as they were established

during the perceiving of an event or object. Thus, the neural ensemble, the original patterns of activity, fires simultaneously and experience is recalled as a whole unitary event, and not as separate categorisations (Longo, Anderson and Wicht, 2002). This whole unitary event or picture is realised when using knowledge representation strategies such as mind mapping.

Buzan (1977, 2002, 2003) explained that the mind mapping method takes into account that the two halves of the human brain are performing different tasks which help students to structure their learning environment actively. Laight (2004) reported that students should be taught and encouraged to create mind maps in the interest of fostering a more self-directed teaching and learning activity that will also benefit study skills. Other studies have shown the importance of mind maps in making connections or associations of concepts in the learning of science and mathematics (Benyahia, 2005; Buzan and Buzan, 2003; DePotter and Hernacki, 1993; Entrekin, 1994; Farrand, Hussain and Hennessy, 2002; Margulies and Maal, 2002; Plotnick, 1997). Mind maps are an educational strategy that can shift control from teacher to learner and, as a result, hold the potential to improve academic achievement (Kinchin, 2000; Peterson and Snyder, 1998).

Like all teaching tools, mind mapping is not a cure; it will not suit all learners or all learning situations. However, it is hypothesized that the use of a mind-mapping technique will further enrich the classroom learning environment and improve student academic outcomes. The authors have not come across a research study that combined these three techniques, globally or locally in Brunei Darussalam, where there is a serious need for improvement of student learning outcomes to meet the nation's human resources demand. It was therefore decided to use a teaching package that involved the use of technology, mind-mapping and constructivist teaching and learning and compare its effectiveness to a traditional approach.

The gender issue is an intriguing factor being investigated in many educational research studies. For example, gender differences in General Science (Young and Fraser, 1994; Beller and Gafni, 1996), Biology (Soyibo, 1999; Burns and Bracy, 2001; Zoller and Ben-Chaim, 1990), Chemistry (Klainin, Fensham and West, 1989; Forrest, 1992) and Physics (Forrest, 1992, 1993) achievement scores have been reported. These differences are responsible for causing a gender gap in enrolment in certain programmes at institutions of higher education. Jovanovic and Dreves (1995) have advocated a need to minimise gender differences in student academic achievement to help avoid an imbalance in social development. There is a special need to consider this issue in Brunei because female student enrolment at institutions of higher education has increased remarkably. For example, recent statistics show that for every male students there are about 2.2 females at the University Brunei Darussalam.

Aims

The purpose of this study was to compare the achievements of students taught using a constructivist-visual mind map approach (CMA) and a traditional teaching approach (TTA). This study is an attempt to answer the following research questions.

- (i) How do the CMA and TTA students' achievements compare?

- (ii) How do the effects of gender on CMA and TTA students' achievements compare?
- (iii) How do the mean achievements of male and female CMA and TTA students compare?

Methodology

Sample

The samples of the study involved six classes of Form 3 (Year 9) students. A total of 140 students (aged 13 to 15 years) were involved. Three of the six classes were taught using the TTA and this group was called the traditional teaching approach group. The other three classes were taught using a CMA and this group was called the constructivist-visual mind map approach group. There were 70 students (40 boys and 30 girls) in the TTA group and also 70 students (41 boys and 29 girls) in the CMA group.

Content and achievement test

In this study, the students learnt a topic on magnetism which is the final unit in the Form 3 syllabus. The topics covered were magnets, magnetic field, electromagnets, and application of magnetism. The achievement test consisted of eleven multiple-choice, three short answers and a descriptive essay-type question. For each multiple-choice question, the students were required to select one correct answer out of four given options. Questions were taken from past PMB examination papers. PMB is the Bruneian Lower Secondary (Form 3) national examination. The questions were further classified using Bloom's taxonomy of educational objectives.

Introduction to mind-mapping

Before the intervention, the CMA students in their respective groups were introduced to the basic guidelines for creating the foundation structures of a mind map. The set of mind mapping guidelines used in this study were developed by Buzan and Buzan (1993) and Margulies and Maal (2002). CMA students were guided to create individual mind maps (IMM) on an A4 sheet of paper several times. They were later guided to make a group mind map (GMM) on a sample topic given to the group. Once the group established their GMM, the intervention phase of the research started.

Intervention stages and data processing procedures

The intervention using both TTA and the CMA was conducted in three stages. In the first stage, an achievement test was administered to TTA and CMA students as a pre-test before the start of the intervention. In stage two, both groups learnt the assigned content on magnetism over four weeks. These groups attended two double lessons (60 minutes each) and two single lessons (30 minutes each) per week. The CMA students were taught using the constructivist-visual mind map approach, while the TTA students were taught using the traditional teaching approach. During the TTA lessons, there was no mind mapping, nor group discussions, and no ICT was used. In stage three, the same achievement test was administered to both groups as a post-test.

The pre-test, post-test and gain scores (for complete test and its sections) were analysed for gender differences. The extent of the difference for a comparison was

evaluated by computing effect size value and then by comparing it to Cohen's (1999) classification that is small, medium and large.

Interventions

During the first intervention lesson, CMA students were divided into groups and then the teacher taught the topic on magnetism using PowerPoint. The teacher highlighted the important concepts and keywords that the CMA students used to prepare group mind map (GMM). Once the teacher presentation was over, each group was asked to construct their own GMM. Later, the students compared their GMM with the teacher's mind maps (TMM). The lesson ended with a discussion on how to construct an individual mind map (IMM) as homework to be submitted next lesson. The second and subsequent lessons started with checking of homework for any difficulties faced by the students. The previous lesson was then revised in groups using GMM. The lesson continued following the procedure described for the first lesson. The unique part of the subsequent lessons was that the previous homework in each submission grew in size in the form of IMM as all the information from the previous lesson(s) was included. Moreover, at the end of the topic each CMA student had reconstructed their own version of the complete IMM on the taught magnetism topic on one or two pieces of A3 paper.

The TTA students were taught according to the teacher's own style of teaching the magnetism topic. All the lessons were conducted in the science laboratory, presented in a traditional way using overhead slides and focused mostly on listening, reading with a textbook and copying notes from the whiteboard.

Results

The results of this study are described in three sections. These sections specifically deal with the research questions reported under the aims section.

How do the CMA and TTA students' achievements compare?

Table 1 shows the analysis results for the pre- and post-intervention mean achievement test scores for the total test as well as scores for the MCQ, structured questions and essay sections for both the CMA and TTA groups. The data in Table 1 shows that the pre-intervention mean achievement test scores for CMA and TTA students were not significantly different ($p = 0.396$, $ES = 0.16$). Therefore, based on these data it was concluded that students in both groups were comparable on the topic related prior knowledge. The post-intervention mean achievement test score of the CMA students was significantly ($p = 0.003$) higher than that of the TTA students. The effect size value of 0.57 suggests that the difference was of medium level, therefore it was of educational value. Moreover, when gain scores were compared, nett gain for CMA students (31.84) compared to TTA students (24.49) were significantly higher ($p = 0.017$) with a medium-sized effect of 0.46. It implies that a CMM teaching approach is more effective than a TTA.

A comparison of mean scores on the components of the CMA and TTA students also reveals similar results as described in the previous section. The pre-intervention mean achievement test scores on the MCQ section of CMA and TTA students were comparable to begin with. However, the post-intervention mean achievement test score

of the CMA students was significantly ($p = 0.05$) higher than that of the TTA students with a marginally medium-sized effect value of 0.37. Moreover, when gain scores were compared, gain scores for CMA students (35.12) compared to TTA (25.93) students was significantly ($p = 0.012$) higher with marginally medium-sized effect of 0.48.

The pre-intervention mean achievement test scores for CMA compared to TTA students on the structured question section were significantly higher ($p = 0.006$, $ES = 0.54$), whereas the difference in post-intervention mean achievement test scores was not significantly different. Moreover, the gain scores were also not significantly different ($p = 0.619$, $ES = 0.09$).

Section	Test	Group	Mean (%)	SD	<i>t</i> -value (CMA vs TTA)	<i>p</i> -value	ES
Total	Pre	CMA	26.15	11.27	0.85	0.396	0.16
		TTA	24.32	11.35			
	Post	CMA	57.99	13.54	3.09	0.003*	0.57
		TTA	48.81	17.84			
	Gain	CMA	31.84	14.61	2.41	0.017*	0.46
		TTA	24.49	17.15			
MCQ	Pre	CMA	32.09	16.40	-0.96	0.338	0.18
		TTA	35.02	15.82			
	Post	CMA	67.20	13.86	1.96	0.053*	0.37
		TTA	60.95	18.95			
	Gain	CMA	35.12	18.63	2.54	0.012*	0.48
		TTA	25.93	19.34			
Structured questions	Pre	CMA	33.82	27.31	2.83	0.006*	0.54
		TTA	20.08	24.07			
	Post	CMA	57.35	32.90	1.44	0.154	0.27
		TTA	47.54	39.45			
	Gain	CMA	23.53	43.99	-0.50	0.619	0.09
		TTA	27.46	39.45			
Essay	Pre	CMA	6.96	6.64	2.40	0.018*	0.45
		TTA	4.18	5.64			
	Post	CMA	38.24	19.02	4.65	0.000*	0.90
		TTA	23.11	14.58			
	Gain	CMA	31.27	17.43	4.15	0.000*	0.79
		TTA	18.93	14.06			

* $p < 0.05$; ES: Effect Size; CMA (N = 51) and TTA (N = 61).

Table 1: Mean pre-test, post-test and gain scores for CMA and TTA students.

A comparison of the pre-intervention mean achievement test scores of the essay section for CMA and TTA students was not comparable (CMA > TTA) to begin with ($p = 0.018$, $ES = 0.45$). However, the post-intervention mean achievement test score of the CMA students was still significantly higher ($p = 0.000$) than that of the TTA students with a large-sized effect value of 0.90. Moreover, when gain scores were com-

pared, gain scores for CMA students (31.27) compared to TTA students (18.93) were significantly ($p = 0.000$) higher with a marginally large-sized effect of 0.79. This suggests that CMA students were better at writing the essay compared to TTA students.

Based on the mean achievement scores and effect size values for the CMA and TTA students, it was concluded that overall the CMA teaching approach learning environment was more effective than the TTA environment in improving students' mean achievement on the magnetism topic.

How do the effects of gender on CMA and TTA students' achievements compare?

This section compares gender difference in achievement of TTA and CMA students for the total test and its sections. The achievements of male TTA and CMA as well as of female TTA and CMA students are compared.

Section	Test	Group	Mean (%)	SD	<i>t</i> -value (CMA vs TTA)	<i>p</i> -value	ES
Total	Pre	Male	28.31	11.25	3.32	0.002*	0.86
		Female	19.31	9.48			
	Post	Male	52.61	17.64	1.91	0.061	0.49
		Female	44.03	17.22			
	Gain	Male	24.30	17.99	-0.09	0.925	0.02
		Female	24.72	16.38			
MCQ	Pre	Male	40.64	14.72	3.37	0.001*	0.87
		Female	27.95	14.47			
	Post	Male	67.11	19.12	3.04	0.004*	0.78
		Female	53.20	15.89			
	Gain	Male	26.47	20.19	0.24	0.809	0.06
		Female	25.25	18.59			
Structured questions	Pre	Male	23.53	27.48	1.26	0.212	0.33
		Female	15.74	18.54			
	Post	Male	50.73	37.68	0.71	0.483	0.18
		Female	43.52	41.94			
	Gain	Male	27.21	41.00	-0.06	0.956	0.01
		Female	27.78	38.19			
Essay	Pre	Male	5.00	6.40	1.33	0.187	0.33
		Female	3.15	4.42			
	Post	Male	22.21	12.26	-0.54	0.589	0.14
		Female	24.26	17.25			
	Gain	Male	17.21	12.56	-1.08	0.285	0.28
		Female	21.11	15.71			

* $p < 0.05$; ES: Effect Size, Male ($N = 34$) and Female ($N = 27$).

Table 2: Mean pre-test, post-test and gain scores for male and female TTA students.

Comparison of male and female TTA students' achievements

Table 2 shows the *t*-test analysis for the pre- and post-test mean scores on the achieve-

ment test and its components for the male and female TTA students. Pre-test data in the table show significant gender differences in favour of male students ($p = 0.002$, $ES = 0.86$) in the total mean score. However, in post-test data, the difference in mean scores for male and female students was not significantly different. This indicates that the gender difference in achievement scores is reduced as a result of teaching despite a mean score for male students staying higher. Moreover, the gain scores for male and female TTA students were comparable. The data on the sections suggest no gender differences in pre- as well as in post-test scores on the structured questions and essay sections. However, for the MCQ section, the male TTA student pre- and post-test scores were significantly higher ($p = 0.001$ and 0.004 , $ES = 0.87$ and 0.78) compared to that of the female TTA students. However, when gain scores on the MCQ section were considered, nett gain for male TTA students (26.47) compared to female TTA students (25.25) was not significant ($p = 0.809$). A decrease in effect size values from pre (0.87) to post (0.78) indicates a decrease in level of gender difference. Although, at the beginning of the intervention, male TTA students show better performance on the pre-test, after going through the traditional teaching approach, there is a reduction in their gain scores when compared to those for the female TTA students. The TTA in this intervention not only creates gender differences but also a regression in male students performance as a whole. These results indicate that the use of the TTA appears to favour the female students in the learning magnetism topic.

Comparison of male and female CMA students' achievements

Pre-test, post-test and gain data in Table 3 for the total test show non-significant gender difference in achievement. Moreover, the mean achievement data on the sections also suggest insignificant gender differences in student achievement. Unlike the TTA, the CMA did not create gender difference. These results indicate that the use of the CMA could actually improve male students' performance as a whole in the total test and its components without creating any gender difference. It is believed that the CMA has created an environment that is equally complimentary to both male and female students, thus indirectly minimising the regression that exists in male TTA students.

How do the mean achievements of male and female CMA and TTA students compare?

Table 4 shows the independent-sample t -test analysis results of the mean scores on the achievement test and its components for male CMA and TTA students. A comparison of male CMA and TTA student achievement scores revealed no significant difference in pre-test scores for the total test and its sections. The same was true for the post-test scores except for the essay. In this section, the mean achievement score for male CMA students was significantly higher ($p = 0.000$, $ES = 1.04$) than that for male TTA students. The effect size suggest the difference is large and of educational value. Moreover, when gain scores were considered, the gain in achievement scores for the total test and its sections were higher for CMA students. These differences were significant for the total test and its sections except the structured section. For the structured section, the mean gain scores were not significantly ($p = 0.788$, $ES = 0.07$) different. However, when mean gain scores were considered, the gain scores for the total test as well as for the MCQ and essay sections were significantly higher for male CMA students. These results suggest superior overall achievement for male CMA students.

Section	Test	Group	Mean (%)	SD	<i>t</i> -value (CMA vs TTA)	<i>p</i> -value	ES
Total	Pre	Male	25.39	12.26	-0.55	0.583	0.16
		Female	27.16	10.00			
	Post	Male	59.27	13.75	0.77	0.445	0.22
		Female	56.31	13.39			
	Gain	Male	33.88	16.50	1.15	0.256	0.32
		Female	29.15	11.48			
MCQ	Pre	Male	31.66	17.29	-0.21	0.835	0.04
		Female	32.64	15.53			
	Post	Male	68.34	15.10	0.67	0.507	0.19
		Female	65.70	12.21			
	Gain	Male	36.68	20.11	0.68	0.498	0.19
		Female	33.06	16.73			
Structured questions	Pre	Male	31.90	29.04	-0.58	0.568	0.16
		Female	36.36	25.27			
	Post	Male	62.07	32.47	1.18	0.244	0.33
		Female	51.14	33.16			
	Gain	Male	30.17	45.99	1.25	0.219	0.35
		Female	14.77	40.58			
Essay	Pre	Male	6.38	6.67	-0.72	0.478	0.20
		Female	7.73	6.68			
	Post	Male	37.07	16.39	-0.50	0.620	0.14
		Female	39.77	22.33			
	Gain	Male	30.69	16.89	-0.27	0.786	0.08
		Female	32.05	18.49			

* $p < 0.05$; ES: Effect Size; Male (N = 29) and Female (N = 22).

Table 3: Mean pre-test, post-test and gain scores for male and female CMA students.

Mean achievements of female CMA and TTA students

Table 5 shows the independent-sample *t*-test analysis results of the mean scores on the achievement test and its components for the female TTA and CMA students. A comparison of female CMA and TTA student achievement scores reveals that, to start with, the female CMA group achieved higher scores than the female TTA group for total test and sections except the MCQ. The post-test data also suggest that female CMA student mean achievement scores were higher on the total test as well as its sections except for the structured questions. However, the gain scores data reveal that female CMA and TTA students were comparable on the total test and its sections except for the essay section, where female CMA students were superior.

Discussions

The results of this study demonstrate that mean achievement of CMA students was higher than that of TTA students. This is in line with previous studies that show that

Section	Test	Group	Mean (%)	SD	<i>t</i> -value (CMA vs TTA)	<i>p</i> -value	ES
Total	Pre	CMA	25.39	12.26	-0.99	0.328	0.25
		TTA	28.31	11.25			
	Post	CMA	59.27	13.75	1.65	0.104	0.42
		TTA	52.61	17.64			
	Gain	CMA	33.88	16.50	2.19	0.033*	0.55
		TTA	24.30	17.99			
MCQ	Pre	CMA	31.66	17.29	-2.23	0.030*	0.56
		TTA	40.64	14.72			
	Post	CMA	68.34	15.10	0.28	0.781	0.07
		TTA	67.11	19.12			
	Gain	CMA	36.68	20.11	2.00	0.050*	0.51
		TTA	26.47	20.19			
Structured questions	Pre	CMA	31.90	29.04	1.17	0.245	0.30
		TTA	23.53	27.48			
	Post	CMA	62.07	32.47	1.27	0.210	0.32
		TTA	50.74	37.68			
	Gain	CMA	30.17	45.99	0.27	0.788	0.07
		TTA	27.21	41.00			
Essay	Pre	CMA	6.38	6.67	0.84	0.406	0.21
		TTA	5.00	6.40			
	Post	CMA	37.07	16.39	4.11	0.000*	1.04
		TTA	22.21	12.26			
	Gain	CMA	30.69	16.89	3.63	0.001*	0.92
		TTA	17.21	12.56			

* $p < 0.05$; ES: Effect Size; CMA (N = 29) and TTA (N = 34).

Table 4: Mean pre-test, post-test and gain scores for male TTA and CMA students.

constructivist teaching (Fisher, 2004; Lorschach and Tobin, 1997) as well as proper use of technology (Barnea and Dori, 1999; Kumar and Helgeson, 2000) for student-centred active learning help students improve their academic achievement. This means more students can study science subjects at upper secondary level. In Brunei, it is necessary for more home students to study science and replace expatriates as teachers.

This study reported that the use of a mind mapping technique within a constructivist learning environment has reduced the gender gap in achievement. This means that both genders can have equal opportunities in studying science subjects at the upper secondary and tertiary levels. At present in Brunei, the number of female students at tertiary level is significantly higher than that of male students. This gender gap in enrolment does have social and economic implications. CMA therefore has good potential for minimising the gender gap in enrolment at institutions of higher education in Brunei. However, it is important that the effectiveness of this technique is tried in other subject areas and with subjects from other cultural backgrounds.

Section	Test	Group	Mean (%)	SD	<i>t</i> -value (CMA vs TTA)	<i>p</i> -value	ES
Total	Pre	CMA	27.16	10.00	2.82	0.007*	0.81
		TTA	19.31	9.48			
	Post	CMA	56.31	13.39	2.74	0.009*	0.79
		TTA	44.03	17.22			
	Gain	CMA	29.15	11.48	1.07	0.290	0.31
		TTA	24.72	16.38			
MCQ	Pre	CMA	32.64	15.53	1.09	0.280	0.31
		TTA	27.95	14.47			
	Post	CMA	65.70	12.21	3.03	0.004*	0.87
		TTA	53.20	15.89			
	Gain	CMA	33.06	16.73	1.53	0.133	0.44
		TTA	25.25	18.59			
Structured questions	Pre	CMA	36.36	25.27	3.29	0.002*	0.95
		TTA	15.74	18.54			
	Post	CMA	51.14	33.16	0.71	0.481	0.20
		TTA	43.52	41.94			
	Gain	CMA	14.77	40.58	-1.15	0.255	0.33
		TTA	27.78	38.19			
Essay	Pre	CMA	7.73	6.68	2.76	0.006*	0.83
		TTA	3.15	4.42			
	Post	CMA	39.77	22.33	2.74	0.009*	0.79
		TTA	24.26	17.25			
	Gain	CMA	32.05	18.49	2.24	0.030*	0.64
		TTA	21.11	15.71			

* $p < 0.05$; ES: Effect Size; CMA (N = 22) and TTA (N = 27).

Table 5: Mean pre-test, post-test and gain scores for female TTA and CMA students.

According to Draves and Coates (2005), there is an emerging pattern after secondary school that more male students prefer the technical and vocational institutions compared to female students. They also stated that at the tertiary level, in non-technical subjects, the number of female students is higher than male students. This does not seem to bode well for Brunei where enrolment of female students in almost all institutions of higher education is higher than that of male students. One of the challenges in education is achieving gender equity in the achievements of students.

In Brunei, a lower number of male students opting for science, especially at the tertiary level, has been associated with their under achievement in science subjects at the secondary level. In this study, it has been observed that CMA technique has selectively helped males to improve their academic achievement without interfering with the achievement of female students. This was essentially required in the country. Since it has been reported that females underachieve in science all over the world, there is a movement to empower females in the field of education in many countries. It

is therefore essential that the CMA is tried in settings where female students need help to investigate if it can selectively help them compete with male students.

CMA allows students to learn collaboratively in order to acquire, construct and re-organise knowledge. This notion gets support from Laight (2004) who stated that learning strategies that enhance active learning should be introduced, whereby students should be taught and encouraged to create mind maps. Thus, if teachers intend to incorporate CMA as a tool for teaching, they can use it to help students improve their achievement.

The present study is different from previous studies because in this study constructivist teaching, technology and mind mapping are married together to produce the desired result. There is a further need to investigate the contributions of these three aspects of the teaching package to the total gain score.

Teachers can use the results of this study to implement this new teaching technique in order to optimise achievement as well as gender equity in students' achievement. Curriculum departments can use this study as a guide to modify the national curriculum. Finally, teacher trainers can use this study to teach their students this technique in methods of teaching courses. Moreover, this study adds to a research base that better equips the ministry of education to make decisions to increase trained nationals in science related fields that are gender equilibrated.

Conclusion

Minimisation of gender differences in achievement has been taken very seriously by researchers and practitioners working in the field of education. In Brunei, gender differences in academic achievement have created a gender gap in enrolment (more females than males) at institutions of higher education. CMA reported in this study has minimised the gender differences in achievement. This technique appears to be a potential solution for overcoming gender differences in science achievement and balancing enrolment at institutions of higher education. This technique has the advantage over the constructivist-informed and interactive whiteboard technology-rich teaching and learning technique (Dhindsa and Emran, 2006; Sharizal-Emran, 2006) reported to minimise gender differences because mind-mapping is much cheaper and more easily used in all classrooms. However, more research with students from different cultures, year levels, different science topics as well as subjects, is recommended to verify the results of this study.

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Investigating the effectiveness of using additional reading material on English learners' attitudes and perceptions related to science

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Abstract

The study was conducted in two basic science classes (one class was experimental and other one was control) at the Southeast Welcome Center, located in Columbus, OH. The objective of the study was to determine whether the use of more reading material in the science class would help to make English as a Second Language (ESL) students' attitudes and perceptions toward science more positive. Data was collected using three instruments; survey, semantic differential, and pre- and post-achievement tests. The data was statistically analysed using the Statistical Package for the Social Sciences (SPSS) and showed that members of both the experimental and control groups had generally positive attitudes both prior to and upon completion of the study. However, the lack of additional reading material in the control group's class did have a negative affect on members of the control group's attitudes toward science compared to the experimental group. There are two reasons that could explain why the attitudes of both groups are not similar towards reading in science: (i) additional material and various teaching strategies have highly motivated students in the experimental group because differentiated instructions and additional reading material may keep students' motivation intact, and (ii) changing the pace in the lessons might increase students' motivation and enjoyment of the lesson. Finally, the study demonstrated that using additional reading material served as a tool to 'deepen' the students' thinking.

Introduction

English language learners have great difficulty in reading and understanding science textbooks. Differentiating between technical terms and everyday English and understanding culture-specific examples are the two greatest difficulties. Reading is an important way for students to gain knowledge in the subject, and is a necessary skill for communicating scientific ideas. By reading, students are able to become independent, lifelong learners and they can separate facts from opinion and accurate from inaccurate content (Ediger, 1995).

Cummins's (1981, 2003) Basic Interpersonal Communicative Skills (BICS) idea is one component of communicative competence, but for students who will be doing academic work in English, more is needed for them to be able to use the language to

read science books, do mathematical word problems, or reflect upon and evaluate history lessons. These latter skills, which he refers to as 'Cognitive Academic Language Proficiency (CALP)' take longer to develop (five to seven years) than BICS, and need to be taught in conjunction with them. By using academic content areas as a basis for the language lesson, the teacher focuses attention on higher-order thinking skills such as analysing, synthesizing, or predicting and provides students with the appropriate language labels and conventions necessary to facilitate class work in that language.

This study is to determine the impact on student attitudes and perceptions of using additional material in the science classroom. The research literature in this area is minimal. Integration of science instruction with reading material makes science more appealing to a diverse group of students and provides students with authentic learning opportunities through real world problems. Additional material give students opportunities to be active learners through an investigative, problem-solving approach that engages them in the use of the science process skills.

This paper is aimed primarily at studying whether additional reading material with visual representations, graphic organisers and filling out worksheet activities in the science classroom towards improvement in ESL¹ student attitudes and perceptions related to science. In order to mainstream these students, their reading and writing skills must be developed through teaching content areas. While conducting this study, I was trying to answer the following questions: (i) does using additional reading material (with visual representations, graphic organisers, role plays, situational dialogues, and problem solving for students working in pairs) in the classroom help to create more positive student attitudes and perceptions toward science and reading?, and (ii) does using additional reading material help students get better scores on achievement tests?

Methodology

The participants in this study were post-secondary students who had been in US schools less than two years. The study was conducted in two science laboratory classes. One class, which was the experimental group was taught in the morning while the second one (the control group) was taught in the afternoon. The experimental group had 30 students (16 males and 14 females) with different reading abilities. The control group was a class of 15 students (8 males and 7 females) with different reading abilities. The participants from the two classes were grouped in two different ways based on their reading abilities and gender. The reading abilities of the students were determined by their assessment scores when they first arrived at the Language Institute Center. Students were also grouped based on gender to determine if female or male students assign a higher value, attention, attitude and effort to reading in the science classroom.

The purpose of the pre-test and pre-survey was not told to the students in order to prevent them from answering the questions in a biased manner. This action research was implemented for eight weeks from 9 February until 10 April 2006. A reading survey was administered at the beginning and at the end of the study. Two types of semantic differential instruments with the heading 'Reading in Science' were given to each student prior to the beginning of the study and again at the completion of the study. The pre- and post-achievement test was the reading of a science article, followed

¹English as a Second Language

by ten questions. The quantitative data collected by means of the pre-test and post-test were subjected to statistical analysis.

Data Sources

Data was collected using three instruments. First, students were given a multiple-choice survey regarding their reading background. Students were asked to show their enjoyment level of reading, self-perceived ability level and whether they found reading a science text to be beneficial.

The project began with a pre-test in the form of the reading of a science article. A time limit of forty-five minutes was given to each student to finish reading. After reading, a ten-question matching test and a graphic organiser called 'Action Map' was given to each student as the pre-test.

In order to measure the students' attitudes and perceptions related to science, two types of semantic differential instruments with the heading 'Reading in Science' were given to each student prior to the beginning of the study and again at the completion of the study. The semantic differentials consisted of twelve word pairs that conveyed positive and negative feelings and perceptions related towards reading in science. The students described their attitudes and perceptions related to reading in science by placing an 'X' mark on one of five lines between the word pairs.

Cronbach's alpha was utilised to determine the reliability of a semantic differential pre-test and post-test. Both the pre-test and post-test semantic differentials measuring attitudes and perceptions related to reading in science were considered for their internal consistency.

Inspection of Table 1 indicates that both attitudinal instruments were reliable for both the pre-test and post-test forms. For the semantic differential measuring attitudes and perceptions related to reading in science, Cronbach's alpha for the pre-test was 0.75 and Cronbach's alpha for the post-test was 0.94.

Variable	No. of items	No. of subjects	Cronbach's alpha
Attitudes and perceptions related to reading in science – <i>Pre-test</i>	12	45	0.75
Attitudes and perceptions related to reading in science – <i>Post-test</i>	12	45	0.94

Table 1: Internal consistency reliability (Cronbach's alpha) for pre- and post-test attitudes and perceptions related to learning, and attitudes and perceptions related to reading science.

Procedure

The focus of this study was to measure whether or not students' attitudes and achievement related to reading in science could be affected by adding supplementary material into the classroom curriculum. This study took place during the regularly scheduled

class period, which was ninety minutes. The background reading survey, two semantic differential evaluations, and pre- and post-achievement tests took place during the class period but students performed their reading assignments inside and outside the classroom.

Both experimental and control groups were taught the same subject and were given the same reading assignments. However, the reading activities of the experimental group included additional material such as visual representations, graphic organisers, role plays, situational dialogues and problem solving for students working in pairs.

The science content covered during the data collection period was molecule, compound, mixture, chemical change, physical change, chemical equations, chemical balance, chemical reactions and various other introductory concepts in chemistry. In both classes, students participated in a variety of activities such as hands-on activities, lectures, cooperative learning activities, individual assignments and discussions.

Students in the experimental group were taught the subject by using additional material such as visual aids, graphic representations, varieties of activities, and articles about the topic. Once given the articles and handouts, students broke up into small groups to read them. After reading the articles and handouts, students answered questions given to them to help focus their attention on points made in the topics that were relevant to class. After a sufficient period of time, the students' opinions about information in the article were discussed. The students summarised the topics by using a graphic organiser. Both groups received some articles, however students of the control group did not perform the twenty activities as the experimental group did in each period.

Students were encouraged to read two hours per week outside of normal class, especially articles or books related to the topic. The reading time was managed by the student. For example, a student could read five nights for twenty-four minutes or three nights for forty minutes. The students kept a daily time log to verify the minutes they spent reading for the duration of the study. Students also performed ten minutes of a reading activity in the classroom everyday. Each week (after two hours of reading), the students wrote two to three paragraphs and used a graphic organiser to summarise their reading. The students repeated the procedure for six weeks. At the end of the project, a post semantic differential and post-achievement test were administered. The same reading survey was also given to the students to check and assess if there was a change in attitudes over the course of the project.

Data analysis

The quantitative data collected by means of the pre-tests and the post-tests were statistically analysed using the Statistical Package for the Social sciences (SPSS). Descriptive statistics including means and standard deviations were determined while *t*-tests were performed among the individual items, as well as among the total scores. Multivariate Analysis of Variance (MANOVA) was used to determine the two-way interaction effects of trial by gender and the main effect of trial according to Wilks' Lambda. Relationships between all independent variables (gender, class) and all dependent variables (pre-test and post-test attitudes and perceptions related to science, pre- and post-achievement tests) were calculated by the Pearson product moment correlation procedure. Finally, the internal consistency reliability estimates of each of the instruments were determined by calculation of Cronbach's alpha.

Results

The first research question of this project was to determine if using additional reading material (with visual representations, graphic organisers, role plays, situational dialogues, and problem solving for students in working pairs) in the classroom helped to create more positive student attitudes and perceptions towards science and reading.

A reliability test performed using SPSS indicated that the semantic differential used to measure students' attitudes and perceptions related to reading in science was fairly reliable. Cronbach's alpha is a measure of the probability that performance on one item of an instrument will correctly predict performance on a subsequent item. The pre-test of and the post-test of the semantic differential had a Cronbach's alpha of 0.75 and 0.94 respectively (see Table 1).

Instrument	Gender	n	M	SD	<i>t</i>	<i>p</i>
Experimental group						
Pre-semantic differential attitude	Male	16	33.00	4.87	1.93	0.031
	Female	14	34.45	3.27		
	Total	30	33.73	4.07		
Post-semantic differential attitude	Male	16	51.50	7.78	1.99	0.029
	Female	14	50.92	7.75		
	Total	30	51.23	7.64		
Control group						
Pre-semantic differential attitude	Male	8	32.50	4.69	1.98	0.023
	Female	7	34.20	3.38		
	Total	15	33.35	4.03		
Post-semantic differential attitude	Male	8	35.50	4.86	2.11	0.033
	Female	7	37.57	3.95		
	Total	15	36.47	4.43		

Table 2: Mean score (M), standard deviation (SD), and *t*-test for pre-test and post-test attitudes and perceptions related to reading in science.

Table 2 provides the mean score (M) and standard deviation (SD) for the experimental and control groups. The dependent variables are pre-test and post-test attitudes and perceptions related to reading in science and pre- and post-achievement tests. The table shows that the pre-semantic differentials attitude toward reading in science of both males and females in the experimental and control groups was almost the same. A *t*-test comparing the pre-test and post-test semantic differentials attitude toward reading in science shows there is no significance between the two. It is important to note that both the control and experimental groups had generally positive attitudes towards reading in science both before and after instruction based on mean semantic differential scores. However, students (both males and females) in the experimental group exhibited more positive attitudes toward reading in science than the control group at the completion of the study.

The second research question was find out if using additional reading material helped students get better scores on achievement tests. As Table 3 shows, the pre-

achievement test mean scores of both the experimental and control groups were 82.10 per cent and 76.60 per cent respectively while the total of the post-achievement test mean scores of the experimental group were 87.73 per cent, and 81.20 per cent for the control group. A *t*-test comparing the pre-test and post-achievement tests shows there is no significance between the two. It can also be noted from these means that all students significantly increased their achievement scores over the course of instruction. This result was not surprising because it was expected that all students would learn content over the course of instruction, regardless of the teaching method used.

Instrument	Gender	n	M	SD	<i>t</i>	<i>p</i>
Experimental group						
Pre-achievement test	Male	16	82.06	7.94	2.23	0.035
	Female	14	82.14	7.35		
	Total	30	82.10	7.54		
Post-achievement test	Male	16	88.25	9.41	2.23	0.037
	Female	14	87.14	4.97		
	Total	30	87.73	7.56		
Control group						
Pre-achievement test	Male	8	76.37	6.30	2.32	0.027
	Female	7	76.85	5.11		
	Total	15	76.60	5.57		
Post-achievement test	Male	8	83.75	6.67	2.11	0.032
	Female	7	78.28	8.59		
	Total	15	81.20	7.87		

Table 3: Mean score (M), standard deviation (SD), and *t*-test for pre- and post-achievement tests score for both the experimental and control groups.

Table 4 shows the results of the analysis of variance (MANOVA), indicating that there was not a significant two-way interaction effect of trial by gender. The results do indicate that the interaction effect of trial by gender may be approaching a level of significance ($F_{(1,20)} = 2.23$, $p = 0.142$).

Source	df	Wilks' Lambda	F	<i>p</i>
within subjects				
Trial	1	0.90	1.15	0.294
Trial by gender	1	0.91	2.23	0.142
Error	20			

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.000$.

Table 4: Multivariate analysis of variance for attitudes and perceptions related to reading in science.

Conclusion

A study by Gilmore (1985) showed that attitude may play a big role in literacy success. The results of this study showed that there was a strong correlation between students' enjoyment of reading science and their self-perceived ability level in both the experimental and control groups. It is clear that when a student has difficulty with reading, he or she cannot enjoy reading, hence this study confirms that there is a positive relationship between the difficulty level of reading and the attitude toward reading. Members of both the experimental group and control group had generally positive attitudes both prior to and upon completion of the study. However, the additional reading material and activities significantly increased the attitudes of students in the experimental group and their reading enjoyment of science. In the meantime, the lack of additional reading material and activities in the control group's class did have a slightly negative affect on members of the control group's attitudes toward science compared to the experimental group. There are a number of reasons that could explain why the attitudes of both groups are not similar towards reading in science. The first reason could be that additional material and various teaching strategies have highly motivated students in the experimental group because differentiated instructions and additional material may keep students' motivation intact. Also, changing the pace in the lessons, such as lecturing, then moving to small group discussion, including a video in the presentation, or having the students do some 'hands-on' activities as a group might increase students' motivation and enjoyment of the lesson. The second reason could be that students in the experimental group were engaged and busy with a variety of activities during the project. They perceived that the learning activities were intended to engage them in the learning activities and they felt that I had high expectations for their success. Thus, they might have more positive attitudes and perceptions toward reading in science.

As shown in Table 2, the pre-achievement tests of both males and females in the experimental groups had similar scores, which might indicate that this group had similar academic backgrounds. However, the pre-achievement test scores of both males and females in the experimental and control groups were different prior to instruction. The reason could be that both groups had diverse academic backgrounds since they came from different countries and some of them had had no previous schooling.

Students in both the experimental group and the control group showed improvement from pre- to post-achievement tests. Therefore, using the specific instruction neither helped nor hindered student mastery of content. However, the level of achievement and mastery were not similar in both groups. The experimental group had higher scores than the control group on the post-achievement test. If additional reading material and activities had been used in the classroom for a longer period of time, students probably would have been comfortable using this kind of instruction as part of their learning process and then they would have responded to it more positively.

In this study, it was found that there was no significant two-way interaction between gender and changes in attitudes and perceptions related to reading in science (see Table 4). However, both males and females in the experimental and control groups had almost the same attitude towards reading in science (see Table 2). The study demonstrated that students (both males and females) in the experimental group exhibited more positive attitudes toward reading in science than female and male students in the control group at the completion of the study (see table 2).

Finally, additional material and a variety of activities served as a tool to increase “the depth of students’ thinking” because the special instruction and additional material not only revealed student levels of understanding but they also identified concepts that needed further clarification. For this reason, using additional material and a variety of teaching strategies proved to be a valuable tool in the ESL science classroom and increased students’ positive attitudes toward science

Implications for classroom practice

Teachers in all disciplines, especially science, face the challenge of teaching the subjects in their discipline in English to students who are continuing to learn English as a second language. These content-area teachers are sometimes surprised by students’ low level of English language proficiency and feel frustrated because, although they are experts in their academic fields, they lack the knowledge and skills to deal with language issues in their classrooms. Therefore, they should always incorporate the use of additional reading material and a variety of teaching strategies in their curriculum since ESL students come from a wide variety of educational and cultural backgrounds with heterogeneous learning styles.

Teachers must recognise and build upon classroom success by employing teaching methods which foster active student participation. Through participating in and producing comprehensible output, students will gain not only content-area knowledge but also language proficiency. Because of their educational history, students can focus better, and may be more comfortable working in small groups rather than in joining whole class discussions.

Science teachers should make their content input more comprehensible to learners by using visual aids. Visual aids are useful for providing context that helps students understand the linguistic and conceptual input. These include notes written on the board or shown in a multimedia format, as well as photos, illustrations, charts, or graphs – all of which support students’ understanding of content. Teachers must connect previous knowledge and present knowledge about the topic since they do not know students’ academic backgrounds. In this way, students have the chance to apply what they have learnt to a new problem. The lessons should also be connected with real life experiences and be personally relevant, socially meaningful, and academically challenging.

Finally, science teachers are not just assistants to knowledge construction but are researchers. They must continually evaluate the effectiveness of their instructional techniques and make necessary changes in their classroom practice. This is a never-ending cycle that must not be looked upon as extra work.

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Issues surrounding academic integrity in the Middle East

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Abstract

There is a general impression amongst many teachers in Middle Eastern countries that issues of academic integrity, especially academic dishonesty, are more prevalent in this region than other parts of the world. In this paper it is our intention to demonstrate that the problem of academic dishonesty is a worldwide issue and not unique to the Middle East. We will explore some of the current issues associated with academic integrity and offer suggestions to promote it, to endorse it, and to prevent academic dishonesty. We will also explore ways of fostering academic integrity at the institutional level, with specific reference to the systemic approach taken by the Foundation Program at The Petroleum Institute in Abu Dhabi.

Introduction

Academic integrity is a crucial issue in society as a whole, not just in education. One of the most publicised aspects of academic integrity, or lack thereof, is plagiarism. From generally revered figures like Martin Luther King to the often reviled Vladimir Putin, famous public figures are now being accused of plagiarism. International plagiarism conferences are proliferating and there is now an *International Journal for Educational Integrity*. So-called anti-plagiarism websites like *Turnitin*, *MyDropBox* or *EVE* (the Essay Verification Engine) are fast becoming standard tools at many schools and universities around the world. *Glatt Plagiarism* services not only offers a plagiarism detection service and a teaching module, they also offer a Glatt Plagiarism Self-Detection Program (GPSD), a screening program to help detect inadvertent instances of plagiarism (GLATT, n.d.). There has also been a rise in the resources devoted to academic integrity, particularly in the West, with academic integrity officers and departments becoming common features of many educational institutions. However, there is a great deal more to the issue of academic integrity (and its converse academic dishonesty) than just plagiarism.

In this paper the following questions will be discussed: (i) why should we be concerned about academic integrity?; (ii) are acts of academic dishonesty more prevalent than in the past?; (iii) is academic integrity research that is done in other countries

relevant to the Middle East?; (iv) are the attitudes of students in the Middle East appreciably different from students in other parts of the world?; and (v) how can we as education professionals work to promote an institutional culture of Academic Integrity? Finally, as a case study, the experience of the Foundation Program Academic Integrity Task Force at The Petroleum Institute in Abu Dhabi will be examined.

Why we need to be concerned with academic integrity

Why the entire furor over academic integrity? The statistics on student cheating and academic honesty are alarming. Large scale surveys done by Trevinio, Butterfield and McCabe (McCabe and Drinan, 1999) found that more than seventy-five per cent of undergraduate students had engaged in serious cheating at least once during their academic career. The numbers of students cheating is similar to an earlier survey conducted by Bowers (1964), as referred to by Shropshire (1997), where seventy per cent of students had admitted to some form of cheating. The high percentage of student cheating had prompted numerous debates and discussions by the press and the public on the erosion of moral standards and ethical values in higher education institutes. Indeed, Fass (1990) found a strong correlation between academic cheating and unethical practices in students' later professional lives (Fass, 1990, cited in Ogilby, 1995).

Predictably, then, several studies report a prevalence of academic dishonesty at the tertiary level. De Lambert, Ellen and Taylor (2006) cite a number of studies, '... indicating a range of between 67% and 86% of students involved in acts of dishonest practice, with a greater number of male students than female students admitting to acting dishonestly'. Passow, Mayhew, Finelli, Harding and Carpenter (2006) acknowledge this variability, but maintains '[A]cademic dishonesty (cheating) has been prevalent on college campuses for decades' (p. 643).

In fact, there is little empirical evidence to support the view of increasing cheating and plagiarism among modern students. According to Park (2003) '[L]ongitudinal and time series data on student cheating are thin on the ground, but the evidence suggests that it is becoming more common'. Not surprisingly, he cites only two research studies to support this view; McCabe and Bowers (1994) who 'discovered a dramatic increase in self-reported cheating among male undergraduate college students between 1963 and 1991' and Diekhoff, LaBeff, Clark, Williams, Francis and Haines (1996) [who] found a significant rise in cheating by US college students between 1984 and 1994' (p. 478). Marshall and Garry (2005) stated: '[T]here is the general, if perhaps not yet well supported, belief that students are now more predisposed to engage in dishonest practices during their studies'.

Some students commit acts of academic dishonesty. This probably has always been the case and probably always will be. In the not so distant past, detecting plagiarism and assembling evidence could be a time-consuming business. Larkham and Manns (2002) noted 'the time necessary to untangle plagiarised sources can be significant. This is compounded by... the institution's pressure to begin proceedings as soon as cheating is suspected... Amassing the requisite amount and standard of evidence in [the sample case study] required the member of staff to spend 16 hours to identify textual correlations in the space of three days' (p.347). Whether or not students are cheating more, academics, using tools on the Internet such as Google and so-called anti-plagiarism

software, are now catching more students with much less effort. Unfortunately, this increased publicity about incidents of academic misconduct, especially plagiarism, has not been entirely positive. When the media is filled with news of students cheating, and the new preventative methods academics are developing to combat the problem, the clear implication is that cheating is becoming ever more common on campus. Thus, the reputation of educational institutions, students, and professional academics in general is damaged in the public view.

As always, those students who are inclined to cheat are extraordinarily clever when it comes to finding new ways to beat the system. Many institutions have banned devices such as mobile phones, Blackberries, and palm pilots from being taken into examination halls in an effort to prevent such 'creativity'. On-line plagiarism is also getting easier and cheaper. Hundreds of Internet sites selling all manner of academic papers are easily accessible to anyone. Some of these sites have their own supplies of scholars who will produce tailor-made papers for a price. If this is not enough, the *Khaleej Times* (14 June, 2006), a newspaper in the United Arab Emirates (UAE), reported that some students are 'out-sourcing' their assignments to legitimate websites from India, and Eastern European countries at drastically reduced prices. MacLeod (2006) commented '[T]his has nothing to do with plagiarism, but hiring a freelancer to write 'your' assignments is a clear case of fraud and should highlight just how useless a punitive 'us versus them' academic culture is. No matter how diligent the academics are in pursuing cheating, students who are alienated from the academic culture of their discipline will find ever more creative ways to cheat'.

Whitley and Keith-Spiegel (2002, pp. 4–6) gave eight reasons why educators should be concerned about Academic dishonesty:

1. Equity – Honest students may be disadvantaged by students who cheat to get better marks especially when they are competing for placements in professional or graduate schools. Class grade averages may be inflated and thus distort class performance in general. In order to provide a level playing field for all students, educators have an ethical obligation to address this inequity.
2. Character development – Like it or not, teachers are role models and thus influence their students' development both morally and ethically. Teachers who failed to address instances of academic dishonesty in their classes may indirectly promote more student cheating because the students may interpret that cheating is acceptable or is permissible. Others go further in challenging higher education to renew the interest of moral and civic education in order to influence 'student lifelong learning'.
3. The mission to transfer knowledge – A central objective of any institution of learning must be the transfer and dissemination of knowledge to their students. Failure to address academic integrity may rob students of the necessary knowledge and intellectual acquisitions required to pursue their education.
4. Student morale – Tolerance of academic dishonesty may negatively affect student morale. If cheating is seen as a way to advance one's education progress, it may influence some normally honest students to abandon effort in favour of cheating in order to progress.

5. Teacher morale – Tolerance or indifference to academic dishonesty by any institution can have a negative influence on teacher morale. Failure to resolve or to address such issues may prompt normally ethical teachers to turn a blind eye to student cheating.
6. Students' future behaviour – Studies have shown that failure to address cheating at college or university may lead to cheating in future professional life.
7. Reputation of the institution – Since cheating incidences are newsworthy items, an institution's reputation may be negatively affected if frequent incidents of academic dishonesty are reported by the press.
8. Public confidence in higher education – With recent news reports on increasing instances of academic dishonesty in colleges and universities, possible loss of public confidence can result in loss of public support for higher education.

Relevance to the Middle East

Most of the research quoted above was done in the United States or other Western countries. Is it relevant to the Middle East? Obviously, it is important that academic institutions in the UAE not only maintain the strictest standards of academic integrity, but also that they are perceived to be maintaining high standards. While there have been few, if any, formal studies done on academic integrity in the UAE, in the authors' experience, a significant number of academics in tertiary institutions here have a perception that cheating is more common here than in their home countries. While we obviously cannot refute this assertion with hard data, we maintain that levels of academic integrity here are not better or worse than in any other country. According to Moeck (2002), the cultural diversity of the student body and cultural differences between students and teachers presents a challenge to standardising a universally applicable definition of academic dishonesty. In the literature about academic integrity, international students, or students whose first language is not English, are seen to be persistent plagiarists (Dyck, 2004; Liu 2005; Tysome 2006). The problem with this view as Liu (2005) asserts is that it is simply wrong. Secondly, if native speakers of English often plagiarise inadvertently why should we expect anything else from non-native speakers of English (NNSE)? In a study of ESL¹ college students, Evans and Youmans (2000) had students negotiate definitions of acceptable work with experienced peers and teachers and found '...that such socially situated discourse is necessary for students to grasp generally agreed upon definitions of, and beliefs and attitudes toward, such complex academic issues'. This demonstrates that if NNSE are integrated into the academic culture of their institution then incidents of academic dishonesty can be drastically reduced.

Hunt (2002) argues convincingly in 'Four reasons to be happy about Internet plagiarism' that this challenge to academic standards could be a good thing if it leads to reform that makes higher education more meaningful to students. He suggests that if students saw value in what they are supposed to be learning; as opposed to valuing only the degree or certificate that validates their learning; then academic integrity would no

¹English as a Second Language

longer be an issue. Indeed, some see the increased focus in societies on gaining qualifications for meaningful employment, as opposed to gaining knowledge or skills as a means to do a job competently, as one of the major reasons why students are tempted to cheat.

How to foster a culture of academic integrity at the institutional level

Aside from recognising that academic integrity must be incorporated as a core institutional value, Professor Donald McCabe of Rutgers University, New Jersey, founder of the Centre of Academic Integrity, devised the following seven recommendations for any higher education institution (McCabe and the Fundamental Values Project, 1999).

1. Have clear academic integrity statements, policies, and procedures that are consistently implemented.
2. Inform and educate the entire community regarding academic integrity policies and procedures.
3. Promulgate and rigorously practise these policies and procedures from the top down, and provide support to those who faithfully follow and uphold them.
4. Have a clear, accessible, and equitable system to adjudicate suspected violation of policy.
5. Develop programmes to promote academic integrity among all segments of the campus community. These programmes should go beyond repudiation of academic dishonesty and include discussions about the importance of academic integrity and its connection to broader ethical issues and concerns.
6. Be alert to trends in higher education and technology affecting academic integrity on campus.
7. Regularly assess the effectiveness of its policies and procedures and take steps to improve and rejuvenate them.

Academic integrity at The Petroleum Institute

In response to the desire to maintain The Petroleum Institute's academic integrity policy and culture at the highest possible levels, the Foundation Program Academic Integrity Task Force (FAITF) was formed in the autumn of 2005. The volunteer task force consisted of five members: the chair, and four others representing the four disciplines (Computing, English, Mathematics, and Science) of the Foundation Program. The Foundation Program Director served as a mentor to the task force. The mandate of the task force was to:

- plan a strategy for applying policy consistently within the Foundation Program;
- recommend how the recording of instances of academic dishonesty can be improved;

- recommend how academic integrity can be promoted in a more efficient manner amongst academics and students; and
- make formal recommendations to senior management with a plan of action for all of the above with The Petroleum Institute.

By the end of the academic year in June 2006, the task force had successfully fulfilled the majority of its goals and objectives by producing a staff academic integrity handbook, an academic integrity brochure for students, and a set of recommendations for senior management. An online Academic Integrity Management System (AIMS) to track instances of academic dishonesty was also developed with the help of the IT department along with protocols for dealing with repeat offenders.

AIMS was launched at the beginning of autumn 2006 and academic integrity workshops were held for teachers and students. In addition, an academic integrity officer and two deputies (one for each campus) were appointed. Follow-up workshops are slated for the spring semester 2007.

Conclusion

According to studies done by numerous well-known researchers on issues of academic integrity, there are significant numbers of students cheating. Acts of academic dishonesty are not a recent phenomenon; as long as students are being assessed, some of them will cheat. However, despite media reports to the contrary, there is little evidence that instances of academic dishonesty are on the increase. Nevertheless, academic integrity is a crucial issue because the perception of rampant cheating is as damaging to the values and standing of education as if it were reality.

There is almost no data on academic integrity in the UAE or from other countries within the region. Thus, there is no proof that student cheating in this region is more prevalent than in the West. Research shows that students and teachers all over the world have different views of what constitutes academic integrity, which serves to further emphasize the need for education and acculturation of students into the academic culture of the institution.

Developing or enhancing a culture of academic integrity that emphasizes proper student behaviour coupled with institutional commitment and a fair, consistent, institutional response is a crucial undertaking for any educational institution that seeks to properly educate its students for the future and to maintain a good institutional reputation. Once such a culture is established it must be carefully maintained. The Petroleum Institute academic integrity initiative contributed to a positive culture of academic integrity at the authors' host institute. However, such policies, practices and procedures need to be regularly reviewed, improved, and updated. Further studies on academic integrity in this region are needed to inform local policy and practice with regard to this crucial subject.

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The mini-exam project for large groups of students

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Abstract

The Foundation Program at Qatar University was established as a bridge between secondary school and university. The number of students is between 1400–1800 divided into levels and groups taught by several teachers. Several obstacles face students during their stay in the programme. Students find it hard to adapt to new study habits; common examinations were challenging to students due to the fact that different levels of quizzes was given by teachers. The mini-exam project was introduced as an extra tool to improve student learning, regulate their study, and to ensure their exposure to examination problem standards (challenging problems) with a minimal penalty on their overall course grade. The result was surprisingly encouraging and the mini-exam project has been adapted by the Foundation Program. It is an excellent tool not only for Mathematics and Foundation but also for all programmes that have a large number of students divided into several groups.

Introduction

Making the transition from secondary school to university has never been an easy task for students. Many students struggle during their first year at university due to the many obstacles and challenges they face. One of the main challenges is changing their study habits, such as studying for the examinations in advance, taking the quizzes seriously, and dealing with the pressure of having more than one examination on the same day. In Qatar, and other Gulf countries as well, secondary school students are used to having questions on the examination that are similar if not the same as those seen in class, with little or no change. First year students realise this problem when they take their first examination by when it is too little too late.

Another obstacle first-year students face is that some subjects required for several majors (first-year calculus as an example) have a large number of students divided into a large number of groups (an average of 25 groups of between 20 to 25 students per group). These groups are taught by at least ten different teachers, with different styles of teaching and, most importantly, different levels of difficulties in their quizzes. So some students reach the final examination well prepared for the level of difficulty of the questions on the examinations while others feel shocked when they see the examination.

For the reasons mentioned above, the mini-exam project was established at the foundation level at Qatar University in order to regulate students' study habits and expose them to more challenging problems with a minimal penalty on their overall course mark. It was first established as a pilot project and now is part of the course structure.

What is it?

It is more than a quiz, but less than an examination (namely, quiz < mini-exam < examination). How does it work? What follows below is a summary of the mini-exam regulations.

- There are four mini-exams per semester. Each is worth two marks of the final mark (a total of eight per cent of the final mark).
- Each mini-exam covers one unit of the syllabus (twenty-five per cent of the syllabus).
- A student needs to get sixty per cent on the mini-exam in order to pass.
- Students are allowed three attempts for each mini-exam (taking a different version on each try).
 - 2 marks are awarded for passing at the first try.
 - 1.5 marks are awarded for passing at the second try.
 - 1 mark is awarded for passing at the third try.
- Mini-exams are taken on a specified date and time within a one- to two-week period.
- Students are responsible for registering for the mini-exam on the date and time that is suitable for them.
- The mini-exams are prepared by the coordinator and administered by the teaching assistants.
- There are six to eight different versions of each mini-exam:
 - Same level of difficulty.
 - Each version has 70–80% of easy, straightforward questions.
 - 20–30% are challenging, combined-ideas questions.

Outcome and effect

Overall passing rate

Table 1 shows the percentage of passing among both genders and overall. This information is to be used to compare the percentage of students passing the course with the effect of the mini-exam on that.

	Female			Male			All		
	Total	Pass	%	Total	Pass	%	Total	Pass	%
All	176	115	65.3	68	39	57.4	244	154	63.1
2004	57	19	33.3	19	5	26.3	76	24	31.6
2005	119	96	80.7	49	34	69.4	168	130	77.4

Table 1: Overall pass rate.

The number of students who took and passed the mini-exam

The number of students taking the mini-exams dropped from one examination to another. This shows that some students lost interest in taking the mini-exams for one reason or another. One of the reasons is that some students had to take all three tries. Another reason is that there were twelve examinations in total (four mini-exams with up to three attempts) within a two-month period in addition to the quizzes and other subject examinations. The recommendation was to reduce the number of attempts to two, and the number of examinations to three.

The passing rate was low for the second mini-exam. The main reason for this was that the second mini-exam was right after the mid-term and students were less interested in studying for it since they had just come out of the mid-term. Comparing the pass rate with the overall pass rate of the course (see Table 1), we see that, except for mini-exam 2, the pass rate is almost the same or higher on the mini-exams as the overall pass rate for male, female and both.

Passed courses versus mini-exams passed

Passing the mini-exams had a big impact on passing the course. Only two students out of forty-nine who did not pass any mini-exam passed the course (three of the total number of students). On the other hand, all students (fifty-five of them) who passed all mini-exams (even after the second or third attempt) passed the course. The percentage of students passing the mini-exams increased the chances of passing the course from three per cent up to one hundred per cent. The performance of students in the mid-term, final, and overall also increased, based on the how many mini-exams they had passed. This could be looked at in two ways. Firstly, good students passed all mini-exams while poorer students did not, and this shows in their performance on the mid-term and final. Secondly, taking the mini-exams and passing them exposed students to more challenging problems, regulated their studies and had an effect on them performing well in the mid-term and final. We believe the second analysis is the more appropriate for reasons that will be discussed latter.

Failed course with versus without mini-exams

What if we cancelled the mini-exams and added that eight per cent to the mid-term weight, would that change the percentage of those passing? A look at Table 2 shows that there is no difference for those students who did not pass the course in terms of passing. The only slight difference is in the average and the maximum marks.

Passed course with versus without mini-exams

Doing the same for those students who passed the course we see that taking away the

	With	Without
Passed	0	0
Average	37.3	38.2
Max.	57	58
Min.	1	1

Table 2: Students who failed the course with and without undertaking the mini-exams.

mini-exams and adding the eight per cent to the mid-term will drop the number of students who passed the course from 63.1% to 50.8%. Thirty would have not passed the course. Not only that but even the average, maximum mark and minimum mark would drop.

	With	Without
Passed	154	124
Average	74.3	69.8
Max.	100	96
Min.	60	52
Percentage	63.1	50.8

Table 3: Students who passed the course with and without undertaking the mini-exams.

Took all four mini-exams regardless of whether or not they passed them

We stated earlier that the second analysis is more appropriate (passed course versus mini-exam passed) for reasons that would be discussed latter. From Table 4 we see that students who took all mini-exams regardless of whether or not they passed them (some did not pass any but they attempted all of them) had better results on the pass rate and course average. Almost seventy-five per cent of students who took all the mini-exams passed the course. Their average on both mini-exams and the course are similar.

	Female	Male	Total
Total number of students	138	50	188
Passed the course	105	35	140
Failed the course	33	15	48
Percentage passing	76.1	70	74.5
Mini-exam average	66.4	67.1	66.8
Course average	69.2	64.8	67.0

Table 4: Performance of students who took all four mini-exams.

Received overall at least 4.8 out 8 possible marks

Does getting a passing mark (sixty per cent) in all mini-exams improve the result? The answer to that is not only, 'Yes it improves it', but also it guarantees passing the course.

A look at Table 5 confirms that. Almost ninety-eight per cent of students who got at least 4.8 out of possible 8 marks on mini-exams passed the course. Only three in that category did not pass the course.

	Female	Male	Total
Total number of students	89	29	118
Passed the course	87	28	115
Failed the course	2	1	3
Percentage passing	97.8	96.6	97.5

Table 5: Passing of mini-exams and overall course improvement.

What do students think?

An online survey was conducted to see what students think and feel about the mini-exams among other related issues. Below is some of the outcome of the survey.

How well did secondary school prepare you for university?

When students were asked this question, the majority felt that secondary school did not prepare them for university (see Table 6). One of the main reasons stated was that the examinations in secondary schools not only do not challenge them enough but also, in some secondary schools, that the questions answered in class are asked in the examinations.

Extremely well	Very well	Well enough	Not enough	Not at all
15%	12%	20%	40%	13%

Table 6: Level of secondary school preparedness for university study.

How helpful were the mini-exams?

The majority of students (about eighty-seven) thought that the mini-exams were helpful, especially in exposing them to examination-type questions as well as regulate their studies, and these two were the main reasons behind starting the project (see Table 7).

Extremely helpful	Very helpful	Helpful enough	Not enough	Not at all
39%	24%	27%	7%	4%

Table 7: Level of help provided by the mini-exams as felt by the student.

How fair were the regulations of the mini-exams (getting full marks for a sixty per cent pass rate)

Opinions varied when students were asked about the fairness of the regulations of the mini-exams. The majority thought it was fair, if not more than just fair, because they

received full marks for getting at least sixty per cent on the mini-exam. Those who thought it was not fair (twenty-six per cent) because students did not receive any marks if they got less than sixty per cent, whereas on other examinations they received the marks they got (see Table 8).

Extremely fair	Very fair	Fair enough	Not enough	Not at all
43%	13%	17%	13%	13%

Table 8: Level of fairness of the regulation used in administering the mini-exams as felt by the student.

How well did the quizzes and mini-exams prepare you for examinations?

Comparing how well the mini-exams prepared students for examinations with how well quizzes did, the result came out in favour of mini-exams in several answers and overall (see Figure 1).

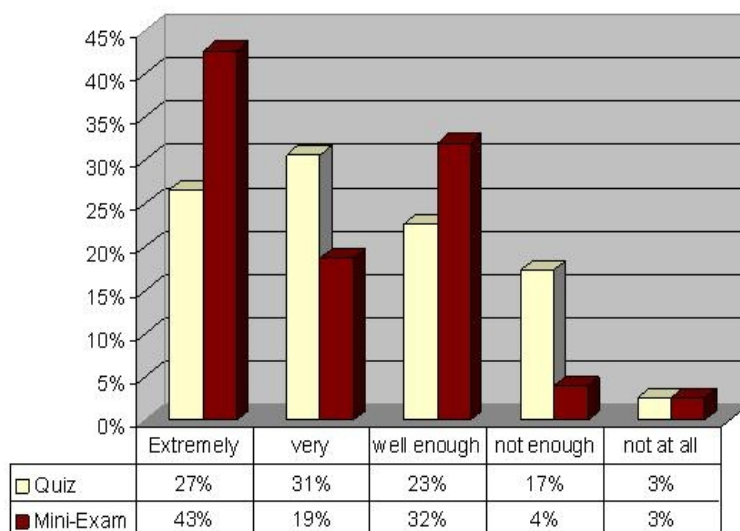


Figure 1: Preparedness for the final examination gained from undertaking quizzes and mini-exams.

How difficult were the quizzes and mini-exams compared to examinations?

In terms of the level of difficulty of the mini-exams and quizzes compared to examinations more than fifty per cent thought that the mini-exams were very or extremely difficult versus thirty-eight per cent who thought the same about quizzes. Yet, as the previous point shows, students still think the mini-exams prepared them well for the examinations because they were more difficult than the quizzes (see Figure 2).

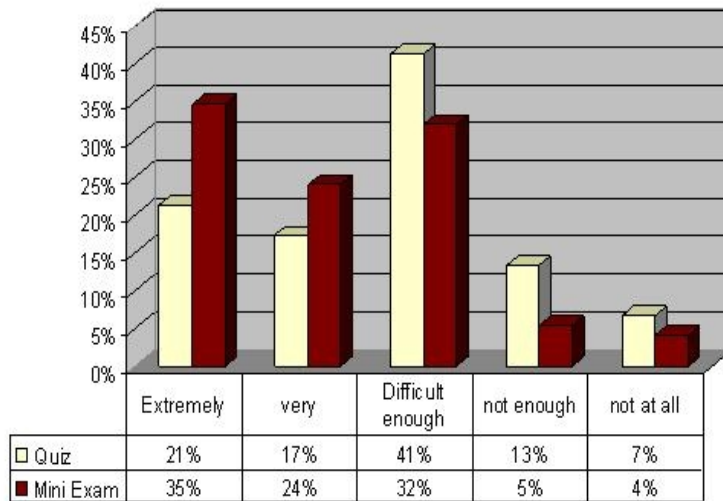


Figure 2: Level of difficulty experienced in the quizzes and mini-exams compared to the final examinations.

Conclusion

As a result of this study the mini-exam was adopted into the course structure of the science major students in the Foundation Program, with a small modification in terms of number of attempts and the marks students received on each attempt.

Improving student thinking in the content area

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Abstract

A large number of hours are spent by teachers lecturing their students in the classroom. Teachers tend to use classroom time for giving instructions, teaching and writing on the board. Students are not given much time to think, or to share ideas about what they are doing in class. They spend their time in class trying to copy down what the teacher is saying. Students are considered passive recipients of content area information. When students are not involved in what is going on around them in the classroom, they tend to get bored, tired and disinterested. Researchers have found that when students participate in what is going on in class, they feel positive about it and their internalisation of the information becomes easier and more manageable. Students feel they own the information that they shared when they have a say in what they are learning. They feel that when they are part of the learning process they can do better, and they tend to appreciate those around them in the learning environment. In this paper, the authors will discuss the negative effects of being a passive learner in the classroom. We will show how important it is for students to be active participants in the learning process. We will also discuss the importance and effect of critical thinking on the learning process. Finally, we will identify ways of using critical thinking in the classroom using the infusion process. Two examples, one from an ICT class activity and another from an English class, will be presented.

Introduction

Students are what educational institutions are all about. They are the reason why schools, colleges and universities are open for business. Kisner (2003) points out that ‘with any educational endeavour, student attitude and involvement are critical to the program’s success. For decades, educators have known that students learn best when the activities are hands-on’ (p. 1). This endeavour puts the students in the driver’s seat where they soar with what information they get in class.

In this paper, we will discuss what passive learning is and its effects on the student within the class. We will show active learning is important to the learning process. We will discuss the importance of critical thinking, its importance, and the effect of critical

thinking on the learning process. We will also discuss how to create a learning environment conducive to the use of critical thinking. Finally, we will identify ways critical thinking in the classroom can be used. Two examples from an Information Technology (IT) class activity will be given on how to use critical thinking in the classroom.

What is passive learning?

Passive learning is thought to happen in a classroom when students sit and listen without participating in what is going on. Students are expected to write down what is being said, noting down every word and every detail (McManus, 2001; Bonwell and Eison, 1991; Byers and Byers, n.d.).

Students in a passive learning environment are not involved in what is going on in the classroom. They are mere observers in the learning process. The emphasis is placed on the lecturer who is the centre of the classroom and no mutual exchange of ideas takes place between the teacher and the student.

Moreover, teachers in such an environment are the holders and disseminators of knowledge. They are in charge of the whole learning and teaching process. The teachers transmit the information and expect the students to come in later and produce it on a short test or examination. The teaching approach in such an environment is teacher-centred, where everything revolves around the teacher.

The effects of being passive learners

As was said above, students in a passive learning environment are not participating in what is going on in class. First, not much creativity or thinking on the part of the students takes place. The students are asked to memorise something, and then produce it when necessary. Second, not much effort is made by the student to try and apply their knowledge to real life situations. The student is expected to take the information as it is without the need for them to connect it to anything or relate it to what is going on in the real world (McManus, 2001). The information they get and produce is done mechanically.

Third, there is no mutual exchange of ideas between the teacher and the students. The teacher does not expect the student to respond to what they say. The student is encouraged to stay silent until the end of the lecture. There is no need to do any analysis, synthesis, or evaluation. Fourth, because the student does not have a say in what is going on in the classroom, they do not own the information that they have; it is someone else's. And because they do not own the information, they tend to forget it. The information is not related to something that could remind the student of events, ideas, discussions or explorations.

Fifth, the student's ability to think or use judgment is diminished. Their critical thinking abilities and their classroom independence tend to be low, depending on others to feed them the information that they want. Finally, the student's motivation level tends to drop when they are not participating in the classroom. They tend to be bored, fall asleep or create conflict with others, all for the purpose of entertaining themselves and relieving themselves of boredom.

What is active learning?

Active learning, on the other hand, occurs when students are provided with opportunities to learn independently from the teacher or from one another. In this type of atmosphere, the student is more involved in the learning process. They are engaged with the teacher in activities that go beyond the mere reception of information. Discussions, explorations, arguments and analyses are some of the techniques used in an active classroom.

As Chickering and Gamson (1987) point out 'learning is not a spectator sport. Students do not learn much just by sitting in classes, listening to teachers, memorising pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves' (p. 3). A student in an active classroom tend to share ideas, evaluate, discuss, read, and weigh what they are learning. The teacher's job is to create an open environment in which students have the freedom to exchange ideas, interpret concepts and explore theories. The teacher in an active classroom are considered as moderators and facilitators. They guide the student by giving them directions as to how to proceed in understanding what is going on. They are there in the classroom to help direct the students by explaining and interpreting the information in a language that the students can understand. The teaching approach in such an environment is student-centred, where the student is responsible for his or her own education.

What is the importance of active learning?

It is important to have an active classroom learning environment. Such an environment is vital for a student's success in the classroom for many reasons. First, the student becomes a willing partners in their education. They tend to take responsibility and take charge of their learning. They are steering their education towards the goals that have been set for them earlier on in their studies. Second, students who are active participants take the knowledge that they get in the classroom, and go out into the real world and apply it to real-life situations that can benefit them in the long run. They test theories, observe, discuss and evaluate things as they apply them to the real world. They get first hand knowledge, information and results as it comes to them from the actual community in which they live.

Third, once students participate and share their ideas and what they are thinking about, they tend to own the information that they contribute in class. It becomes part of their learning culture. It also makes the students proud of the information that they shared. Fourth, those students who involve themselves in class with their ideas about the topics being handled remember that information and retrieve it whenever they are prompted to do so (McKeachie, Pintrich, Yi-Guang and Smith, 1986). Their retention of information becomes higher because they have handled the information, talked about it, tried it and later evaluated it. That information gets fixed in their minds and remembered for a while longer because it has become relevant to what they are doing.

Fifth, the students' ability to think, analyse and use judgment is heightened. The students' ability to use critical thinking in the classroom, and their independence outside the classroom are enhanced. The students take the information and soar with it

to new heights. Finally, the students' motivation level is raised and reinforced when they are active participants in the classroom. They are active in what is going on in the classroom and involved in the subject matter. They enjoy what they are doing in the classroom and are ready to jump in when necessary (Abu-Rmaileh, 2006a, 2006b). The students are consequently encouraged to explore new avenues because they enjoy what they are doing both in and outside of class.

What is critical thinking?

Critical thinking is the process by which students are asked to learn the subject matter and at the same time apply it to the real world. Students also use critical thinking to reach conclusions about every day issues. Schaferman (1991) states that 'all education consists of transmitting to students two different things: (i) the subject matter or discipline content of the course ('what to think'), and (ii) the correct way to understand and evaluate this subject matter ('how to think')' (p. 1). Such a process is called critical thinking.

Researchers also view critical thinking as 'the intellectually disciplined process of actively and skilfully conceptualising, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action' (Scriven and Paul, 2002, p. 1). This process entails working with materials that would allow students to apply such processes. Some of the above processes and techniques could work with some content area material, but not with others. Each content area might require a technique different from the other.

Finally, when students are taught critical thinking, they can take this a step further. They can be taught to use another technique called 'thinking about thinking' which is a higher-order critical thinking technique (Swartz, 2000). This technique allows the students to reach a stage where they think about how they reached the results they reached; they think about the thinking process itself. Thinking about thinking allows students to check and examine the steps that they took to reach the conclusions that they came up with. This higher-order thinking process is taught to students so that when they have similar problems or issues in the future, they can follow the same steps to reach the desired conclusions.

The importance and effect of critical thinking

Critical thinking is not a new term. However, its application has been gaining more attention as it relates to students' ability to use techniques that go beyond the traditional way of teaching and learning. Much research has been done on the use of critical thinking in the classroom.

These days, it is part of the educational culture that students are asked to go through critical thinking in their attempt to learn and use content knowledge. Through the infusion process of classroom content area and critical thinking, teachers can successfully help students direct their thinking to help learn content area matter (Swartz, 2006a). Students become more aware of their learning. They start having a purpose for their

learning, and even if they do not understand that purpose, they still have a chance to analyse and evaluate such information for meaningful use.

The use of critical thinking allows the students to become independent, and less reliant on their teachers. It gives the students the chance to question and engage the teacher and other students in discussions on issues related to the content area. Students can compare and contrast, make decisions, and evaluate the information to which they are exposed.

Creating an atmosphere conducive to critical thinking

As has been mentioned earlier, it is important for the students to use critical thinking in the classroom because it facilitates learning (Lowman, 1984). It also makes the students responsible for their learning. However, before critical thinking occurs, teachers need to create a proper atmosphere conducive to the use of critical thinking. Potts (1994) states that, 'critical thinking in the class is facilitated by a physical and intellectual environment that encourages a spirit of discovery'. Some of the ways teachers can help in building such an environment is by doing the following.

First, create an environment where students are responsible for asking questions and finding answers on their own. One of the most important things that a teacher can do is to create an environment that is conducive to exploration. Once that environment is presented to the student, they become empowered to ask questions that would direct them to solutions to problems they encounter. They become agents of investigative reporting in a climate of critical thinking (Saunders and Kardia, 2006). They also become less restricted in managing their own learning.

Second, build trust with students and be approachable to questions. Part of the open environment is for the teacher to build trust with the students and have mutual cooperation. Students should not be afraid to ask questions about issues that they find to be difficult. Teachers should be the first ones who are open to questions. They should be approachable enough for the students to resort to when in need. The teacher should also encourage and boost student self-confidence to explore and examine different sides of the issues presented to them.

Third, engage students in the learning process. Teachers need to provide hands-on activities for students that allow them to engage in their learning and share in what is going on. Teachers can also use collaborative learning efforts, group discussions or projects that involve all students in the learning process. This would allow students to suggest ideas and solutions to problems of concern. Finally, challenging students to explore what is beyond what was said in the classroom allows the students enough independence to fly with the information that they receive. They get the opportunity to manage and apply such information in the real world (Paulson and Faust, 2002).

Fourth, allow students sufficient time to do assignments and reflect on their ideas. It is important to give students enough time to ponder and think about what they are doing. If they have to ask questions, respond to enquiries, form ideas, generalise, reflect and evaluate ideas, then they need the time to do so. Of course, there are issues that need immediate witty responses. With training, students can be asked to come up with spontaneous answers to questions posed on the spot.

Classroom critical thinking strategies

Numerous strategies and techniques have been used to promote critical thinking in the content area. Some of the strategies might work for one content area, but not for another. It is up to the teacher to decide which strategy works for which subject. In the following section, general methods of critical thinking are outlined. The teacher's role is to decide which ones work for their students and their content area.

Using cooperative learning groups

The most common use of critical thinking is in cooperative learning groups. This is done by placing students in learning groups where they can work together to evaluate and find solutions to problems and issues of concern (Kagan, 1992). Cooper (1995) suggests that with properly structured and organised cooperative groups, students can get constructive feedback from their peers in the groups, from their classroom peers and their teachers.

Using discussions

This way of critical thinking is used where the teacher presents case studies and invites students to share their ideas about these cases. The teacher can either have prepared questions about the content to make it structured, or he or she can ask groups of students to prepare questions for other groups in the classroom to answer. Talking about problems or issues of concern in a public forum provides the students with the confidence to use critical thinking in a constructive manner.

Using questions

In the classroom, using questions is one of the most essential issues in using critical thinking, whether it is questions about how to solve or to talk about issues, or whether it is asking questions about thinking about thinking. This kind of strategy is imperative for critical thinkers, where they think about their thinking process and how they reached the conclusions they arrived at (Paulson and Faust, 2002). Without posing questions, students would find it difficult to deal with the material presented.

Using writing assignments

Writing assignments could be done in different forms. Teachers could ask students to write open and free journals in which the topic is left wide open. Or they can ask students to write focused journals responding to specific questions that target items in the content area. Writing could be done in a way whereby the students are asked to respond to specific issues, using reasoning and deductions to try and argue a certain point, or taking sides about an issue of concern in the course content (Wade, 1995).

Using problem-based learning

Problem-based learning is one of the main methods teachers use to successfully bring about critical thinking in the classroom. It is a tool where teachers give students a question or a problem and the students are to work in groups to come up with solutions to those problems (Peterson, 1997). Each student tackles part of the problem, culminating in a solution. The students go through stages of investigation and evaluation before they come up with their results. At the end, students are required to present their solutions to the problem(s) in question to the whole class, giving them an opportunity to excel and respond to questions.

Using dialogues

These kinds of dialogues or debates could either be written or oral. Robertson and Rane-Szostak (1996) explain how students are given written dialogues to analyse. They then work together in small groups to identify the different viewpoints in the dialogues. They need to find how each person or how each speech is made, what is behind each viewpoint and which has the most weight in the argument. In the oral dialogues or debates, the students are divided into groups, each being assigned a role. Such roles could be a leader role, an opponent, an opinion seeker or an information giver. The students are then asked to play the roles, identifying viewpoints, showing biases, examining reasoning skills, evaluating ethical interpretations and positions, and so on.

Using conference-style learning

In this type of critical thinking, the teacher's role is as the guide or the facilitator of the meeting. Underwood and Wald (1995) describe how the students are asked to read the material ahead of time. They come to class prepared and ready to ask and answer questions. When the students come to class, they sit in a big circle (like a round table) and start asking each other questions relevant to the course. The teacher listens to what the students are doing and steers the discussion by asking specific questions that would focus on the subject matter. The teacher directs the discussion in such a way that the content area is covered and no drifting off the topic takes place.

Using analogies and compare and contrast

Finding similarities and differences, and finding relationships between different issues or problems is one successful way of using critical thinking in the classroom. By having students evaluate those comparisons and analogies, they get to evaluate issues based on merits. They can also make decisions as to what is effective and what is not. At a critical thinking training, Swartz (2006b) suggested that teachers can use open compare and contrast to brainstorm or generate general ideas without a specific goal. They can also use focused compare and contrast with a specific purpose or goal.

Two examples from an IT class activity

There are numerous ways to use critical thinking in the classroom. Thinking about thinking is a tool of higher-order thinking where students describe how their decisions have been reached. The following describes how two approaches to higher-order critical thinking were made and used in the classroom.

The approach

Teachers spend hours planning effective content instruction (lessons) and sometimes the message does not get across. Students are not able to demonstrate how they can do a task given to them. Teaching thinking skills, as well as the processes of infusing analytical skills into content area instruction, enhances understanding. The main goal of this research was to find out whether students can reach conclusions and use reasoning to solve the problems that face them.

Group activities

In this research, the relationship between learning the content and the tasks required to find solutions to issues in the textbook has been studied carefully. To be able to demon-

strate higher-order thinking, two class activities were performed. The first activity was an open compare and contrast activity, and the second was determining parts-whole relationship.

Activity one (compare and contrast)

This lesson was designed around the use of compare and contrast. Before giving the students the timed-task activity, a lesson on infusion thinking was demonstrated in front of the students. Four components of infused thinking lessons were explained: introducing the skill and content, explicit organised thinking, thinking of thinking, and transfer were explained (Swartz, 2006a). The methods were designed to enhance content objectives.

The following instructions were given to students to help them manoeuvre through the work required. Comparing and contrasting are ways of looking at objects and thinking about how they are alike and how they are different. For instance, all objects or files can have a name, a size and other attributes, but there are many ways in which they are different. Maybe they belong to different file groups or types. When you do compare and contrast, it is important to pay attention to all aspects involved.

The students were asked to list the characteristics of two major software applications, (namely, Microsoft Word and PowerPoint) to understand the relationships and differences between those two applications with regard to the features and the interface one has in relation to the other. The students used the software and read material related to the two applications to learn more about their interface and functionality. The students practised the comparing and contrasting skill by finding significant similarities and differences, and determining patterns in the similarities and differences to reach conclusions based on their findings.

The compare and contrast graphic organiser given to the students was a useful tool for gathering details about the items that the students were comparing and contrasting. The graphic organiser helped the students in thinking about similarities and differences between two things (objects, places, events, ideas, projects, etc.). It was used as a tool with which one can brainstorm a list of ways in which items are alike or different.

The students were placed in groups so that they could work together to come up with points to compare and contrast. They were also given the thinking map for comparing and contrasting. This thinking map was used to guide the students in identifying the similarities and differences between the applications in question.

The students were then asked to find how the two applications were alike. The teacher gave the students an example of how they were alike and asked the students to continue for a few minutes more. The teacher discussed similarities, showing which one is more valid than the other. The teacher then shifted topic to talk about the differences in regard to what the students thought was different between what they were comparing. The teacher gave the students an example and asked the students to find more differences and write them down.

For both requirements, the students were asked to brainstorm ideas, noting down all similarities and differences that they could find between the programs. Then, after finishing their lists, the students were asked to eliminate the similarities and differences that they thought were not very important or not relevant to the content learnt. Later, the teacher asked the students to work in groups to come up with a conclusion about which of the applications was suited for tasks like writing and summarising information, long

document versus short slide summary, etc. Finally, the teacher asked the students to look at how the final relevant similarities and differences were derived and how they could find out more about items that were familiar.

Activity two (determining parts–whole relationship)

The second activity was structured around finding the parts–whole relationship in different tasks learnt. The concept behind this activity was to find out how each part of the task was relevant and what role it played in learning the task. It was also about how that task would function properly if a certain part of the task were missing.

The students were given a blank parts–whole graphic organiser to look at for a couple of minutes to identify its parts. The students were also given the thinking map to the determining parts-whole relationship. This map was used to help the students guide their thinking about parts and whole and how each small part makes up the larger whole.

Before the students were given the task to do, they were given an activity to help them do the work. They were given an example of how to identify parts of the whole on a car. The teacher asked the students the following question: ‘What happens when one part of the car, for example, the front light on the car is missing or damaged while driving at night?’ The students were asked to work on finding the functionality of the part of the car and what happened when that part was missing.

After that, along with the students, the teacher discussed the functionality of the missing part, and what happened to the object if that part were missing. The teacher also asked the students to work in groups to show the relationship between the parts and the whole.

Once the students understood how to do the part–whole relationship activity, they were given charts to look at. The students were told that ‘charts are visually appealing and make it easy for users to see comparisons, patterns, and trends in data. Each chart has a set of items or parts that make that chart understandable and complete’. If there were missing parts in the chart, then that chart would be incomplete and difficult to understand. The charts the students were given to look at had all parts of the charts present. The students worked in groups to look at how each chart flowed properly when all parts were present. They looked at the different information that each chart contained and how, when each part was present, it made the chart identifiable. They also looked at how when one part of the chart was missing, it would be difficult to read such a chart.

Later, the students were given charts with missing legends or labels. The students used the critical thinking skills they had learnt in practising and identifying parts–whole relationship. They found out the importance of the legends and labels in comparison to the rest of the parts of the chart. They identified its parts and analysed them. They then made a report about the given data.

The students were then asked to complete the graphic organiser given to them for the parts-whole relationship. They were also asked to answer some questions related to the given chart. The students discussed how hard it was to understand the chart.

The students were also asked if they could make a report with the given chart. They were asked whether the report would be complete with the missing legends. The students discussed the parts of whole graphic organiser, identifying the missing part and showed how important that part was for the chart and how, without such a part, the

information and the report based on that chart would be incomplete.

Higher-order thinking

Thinking about thinking focused student attention on what they did and how they thought about those types of applications, what kind of thinking they did, and how they did the compare and contrast of the two types of applications. They also thought about how different compare and contrast is from the way students usually study concepts in any subject.

For the parts-whole relationship, the thinking about thinking required the students to look at what they did and how they thought about parts-whole, what kind of thinking they did, and how they identified the missing part of the parts of the whole. They also talked about how parts of the whole made sense in using critical thinking to identify incomplete information presented to them.

In the pair-share activity, the students shared and listened to the different thinking manners and different ideas that each group generated. A composite of ideas about the purpose of their discussion were written down. The students came up with reflections on how they were thinking about how they reached the decisions they came up with in the parts of the whole activity.

Conclusion

Students cannot just sit in a classroom, be passive and not get involved in any activities. Students have to be active participants in the learning process. Being an active participant in the classroom is an important part of the learning process.

To be an active participant in the classroom, students have to be able to do critical thinking activities that allow them to be active participants. Before using and applying critical thinking, teachers need to provide an environment conducive to critical thinking. They need to give the students responsibility for their learning, build trust with the students, engage students in the learning process and give them enough time to process the information and reflect on it.

Different strategies are suggested for the use of critical thinking in the classroom. Some strategies might work for one group of learners but not for others. The teacher is to decide which work for which group. Teachers need to pick and choose what is best for their students and for their content area.

The study outlined above shows that students learn their content area by applying examples from real life applications, and at the same time compare their approaches to the tasks required for their class. The study also showed how students can look at things in terms of how one part affects the other parts in the activities they do in class. Once students decipher the intricate requirements of the tasks they are doing (compare and contrast and parts of a whole), they can move to other stages in their higher-order thinking processes.

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Penguins, polar bears and icebergs: Theory and strategies for teaching mathematics and science in a second language

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Abstract

Priming context and structure is a well known but under utilised strategy to improve memory and learning. Neural network modelling of the brain and mind suggests a complication of the learning curve model involving repetition and links at different levels of understanding. The second language setting presents additional cognitive obstacles requiring distinctly refined strategies if students are expected to succeed. We sketch some of the pertinent theory and suggest some practical strategies related to teaching subject context in a second language. We also make some informed suggestions towards the effective use of technology in the mathematics, computing and science classroom.

Introduction: Memory and perception

From early work by Vygotsky and Samuel Renshaw to Kurt Fisher's *Mind, Brain and Education* programme at Harvard University (Fischer, Bernstein and Immordino-Yang, 2007; Fischer and Rose, 1999), the progression of our understanding of how memory and learning occurs has greatly increased in the last hundred years or so. Yet, there has been little progress on the teaching front. A recent *Time Magazine* article puts it clearly, our [US public] schools tend to feel like throwbacks (Wallis and Steptoe, 2006). Is your classroom any different from fifty or even one hundred years ago? Is the highest level of technology change a dry whiteboard marker? Given this reality, what is the state of our understanding of how memory and perception related to learners in these classrooms? New research on memory and the way the brain works, along with the tools of neural network modelling, might mean the end to some of our most cherished ideas. The up side is that some of the teacher's intuitive perceptions turn out to be correct. Let us start with Gestalt theory as a descriptive paradigm.

To apply the category of cause and effect means to find out which parts of nature stand in this relation. Similarly, to apply the Gestalt category means to find out which parts of nature belong as parts to functional wholes,

to discover their position in these wholes, their degree of relative independence, and the articulation of larger wholes into sub-wholes (Koffka, 1935).

As Koffka describes it, the idea of the Gestalt category, or what is now generally referred to as Gestalt psychology, proposes we think holistically and that the ability to perceive and remember relies on the form of the information more than the type of data experienced. In addition, Gestalt and the neural network model suggest that memory self-organises relating to form not data.



Figure 1: Young woman and old woman.

The famous visual illusion pictured in Figure 1 shows us how the mind tends to organise data (Wright, 1992; Fisher, 1968). Looking closely, two possible perceptions are possible; a young woman and an old woman. The perception depends on what part of the image is the start of your apprehension or focus. It is also apparent that the data itself can have an impact on the apprehension of data. Consider the seven character sets listed in Figure 2. Using the Renshaw tachistoscope approach, each of these sets is flashed on a screen for half a second and viewers are asked to attempt to recall as many characters as possible.

Predictably, in a crowd of teachers, Set F is best recalled. It provokes the highest level of response in terms of recognition. During our presentations in the Middle East, we notice that Set E also returns a high level of response with native Arabic speakers, which is understandable since the characters are part of the Arabic language. Set G is the hardest for any one person to keep in memory, since it draws on characters from three different language alphabets.

Set A	24681012
Set B	12345678
Set C	39741050
Set D	210 YFN
Set E	بُحَا وَحَمَارَةُ
Set F	PAY RAISE
Set G	JF0N□5O

Figure 2: Renshaw tachistoscope of characters sets.

Recognition of characters conforming to memorable words or phrases gives an explanation of why acronyms work so well. We can recall a simple list of letters, but we remember better if the list has some addition meaning, or is at least pronounceable as one word. ETA, estimated time of arrival or P2P, peer-to-peer are examples of good acronyms. SOH CAO TOA and BEMDAS are examples in teaching order of operations and relationships in trigonometry:

B – brackets

E – exponents

M – multiplication

D – division

A – addition

S – subtraction

SOH – ‘Sine over hypotenuse’

Further analysis might be extended by asking for written responses. Of interest would be to further classify the most easily remembered perception, Set F: PAY RAISE, between UK-schooled and American-schooled viewers. The regional UK alternative of the phrase would be pay ‘rise’. Thus, for a UK-schooled person, it might be expected that the spelling of the word ‘raise’ is given as ‘rise’. In other words, regional phraseology might overrule the actual phrases flashed. This is supported by experiments where subjects record seeing not what is shown, but what they wanted to see. People do indeed see what they expect to see. And, the complexity suggested by early Gestalt theory was only the beginning.

We now know that the very complex neural network modelling of the brain is the most promising theory going. This theory suggests that neurone cells are organised into very large and complicated intercommunications networks (Fischer and Rose, 1999). These networks are connected hierarchically, but are also cross-connected at various levels. This makes memory mapping a much harder task and it also makes it less obvious how and why learning takes place. Thus, it is understandable if some basic ideas of learning are challenged by new evidence.

Miller (1956) demonstrated that only six to seven characters can be identified out of a group that is flashed on a screen. In the 1940s, Renshaw was able to increase the detail of memory of images by directed practice. This did result in a higher number of characteristics remembered than Miller could reproduce in 1956, but Renshaw’s training was aimed only at visualisation and identification of images of aircraft. Miller and others failed to show that visual identification skills transferred to other areas. Indeed,

little, if any, evidence exists that shows that 'Renshawing', as the skill is referred to, can be transferred at all. Miller and Huitt confirm that situation memory links seem to be fixed around the six or seven mark (Miller 1956; Huitt, 2003).

Obviously, this limitation presents a major obstacle to teaching science or mathematics in the second language setting. The subject of mathematics or science introduces memory links. The second language requires an additional second link. Together they greatly reduce the available memory for thinking.

A cat named George

Many years ago Nancy had a very bad cat named George. He was a real pleasure to have around but had a nasty habit of marking his territory despite her continuous pleas with him to change his behaviour. Eventually a friend who lived outside of town agreed to give George a home in his barn. It was toasty warm in the winter, there were plenty of cool places to hang out in the summer and he could have fresh farm milk every morning. This sounded like an ideal place for George to spend the remainder of his years so off he went. Approximately six weeks later George returned to Nancy's, more than four kilometres in distance. There stood George. He looked the same as the day he was dropped off outside of town. It was amazing what a cat was capable of, and it begs the questions, 'What would a human be capable of doing?' George demonstrates a level or type of intelligence not found in humans. In a similar situation, the average human would be hard pressed to achieve return after a major geographic displacement.

In a similar way, our students differ from teachers in that they have native intelligence in areas we lack, and lacking in areas we are attempting to teach them. We can best approach this by addressing various learning styles that meet the needs of the students. And remember, just because it worked for us does not mean it will work for our students.

For example, when teaching the concept 3 squared times 3 cubed ($3^2 \times 3^3$), we show the students 3 times (2 + 3) is equal to 3 to the power of five. When we have a problem like 3 squared cubed, we show that it is like 3 squared times 3 squared times 3 squared, or 3 to the power of six. It is assumed that once shown we could move onto the next concept. However, we get students who fail to remember when faced with problems with combined items. They just do not get it. We try to come up with ways to help. Nancy has reasoned, since the 3 raised to the power was going up, she would teach the phrase, 'To the sky multiply'. Years later she had a student come up to her repeat over and over, 'To the sky multiply,' with thanks because the phrase made a big difference in her success. The student still remembered how to work exponents years later. Obviously this student needed something to assist the memory of this concept.

In addition to links there is also the issue of the prime learning stage as outlined by Chomsky (1988). Chomsky states that a pigeon learns to fly at approximately two weeks because it has to learn to fly at this time. If you were to keep the pigeon in a box so it can not move its wings until this age and then you let it out of the box, it will fly just as well as any pigeon that has been sitting on the nest all that time. But if you keep it in that box another week or two and then you let it out of the box, it will never learn to fly. It is very probable that language works in the same way.

Most biological capacities have a time at which they have to operate and they will

not operate before or after that time. Chomsky (1988) believes that learning a word for a child is simple because human nature gives us examples that enable us to interpret experiences available to us before we necessarily have the experience. We can learn the label that goes with the pre-existing concept. Chomsky also suspects that something happens to the brain about the time of puberty which triggers this ability to move up a level. This is the prime stage of learning at this logical-deductive level. Denied the actual examples and experiences, students who come to us in university ‘untaught’ have missed the prime time to learn. This does not mean that learning is impossible, since humans are much more flexible learners than pigeons. But it does mean that later life learning needs more work since given the lost opportunity. Further learning must come at the cost of overcoming obstacles including undoing poor or incomplete learning strategies. A major part of encouraging learning at this stage is reintroducing an environment that is more like the prime stage using a diverse medium of delivery, taking advantage of as many experiences as possible.

Icebergs and brains: Levels of understanding

In order to tackle this seemingly massive challenge we always need to keep in mind that students in the United Arab Emirates are second language (L2) students. This brings a whole different set of issues and possible experiences into the picture and briefly we need to look at learning in the L2 environment.

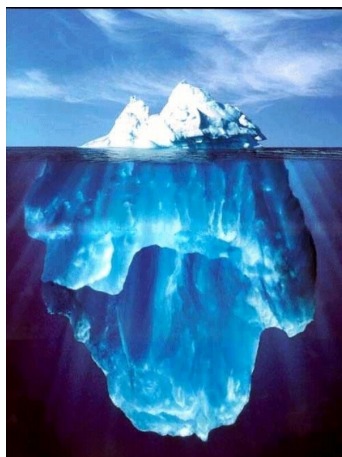


Figure 3: Iceberg off the coast of Newfoundland.

Learning memory can be modelled by the idea of an iceberg, as pictured in Figure 3. Think of the portion of the iceberg below the surface of the water as long term memory. Naturally it contains more information and so it is much larger than the part of the iceberg which is above the water. The part above the water is the working memory, similar to a chalkboard. When our students are engaged in a learning activity the situation is almost like working on a chalkboard, in that if we do not permanently place the

information in our long term memory, or below the surface of the water, it can easily be erased or be forgotten. And, just like an iceberg, the import bits are under the water.

Recall that the magic number seven; the number of simultaneous items that can be productively work on in our working memory. If our chalkboard upper memory gets too full, some information will be erased or lost, due to the overflow of information dealt with at one time. Our L2 students are not only learning the content but they have language issues to deal with as well. Jim Cummins' hypothesis on interdependence of languages (1981) *Iceberg theory* is most helpful when considering how an L2 student learns.

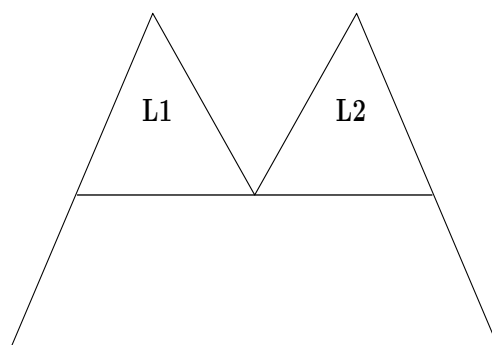


Figure 4: Three-part iceberg (after Cummins, 1981).

Again think of the iceberg but this time think of L2 students. On the surface, the first and second languages appear to be functioning in isolation, but under the surface there are intellectual processes that are common to both languages. When a student is attempting to solve a mathematics problem they are using intellectual processes that are common to both languages. We want the student to be able to transfer concepts from L1 to L2 and we want the student to be able to express knowledge in short term memory procedurally in L2. This takes time and lots of practice.

Cummins' hypothesis is that first language learning proficiencies can be transferred to the second language learning context. The unique aspect of the use of Cummins theory is that this hypothesis could also work in reverse. That is to say, at the same time that learners are learning a second language, they are also developing capacities which could be used in the first language learning setting (Netten and Germain, 2002a, 2002b).

For example, a student is given an order of operations problem like the following:

$$6 + (3 \times 7) - 5 = ?$$

As the student begins the process, they are using their working memory or the part of the iceberg above the water. They learn the principle of solving what is in brackets first, followed by the addition and subtraction as it occurs from left to right. But when the student solves the first step, the multiplication of three times seven, the student will switch to their long term memory and come up with the answer. This will free up space

in their working memory, making this an automatic process. One of our goals is to increase the number of processes that occur. The more often this happens, the more often information in the working memory is minimised. Furthermore, since the mind has the ability to carry out rich complex processes without deliberations, we want to channel as much as possible into long term memory.

Suppose Mohammed, a native Arabic speaker, suffers from a severe head injury and loses his ability to speak and understand. Has he lost his knowledge of Arabic? Not necessarily. As he recovers, his ability to speak and understand Arabic improves and not an ability to speak and understand English. He does so without instruction in Arabic. Had his native language been English, he would have the potential to recover the ability to speak and understand English, not Arabic, also without instruction.

Brain injury cases demonstrate that the human cognitive system have complex connections and levels between long and short term memory. Possession of a certain type of knowledge cannot be identified with the ability to speak and understand. It is not a habit or a skill but a permanent system that constitutes knowing how to speak and understand Arabic. This type of memory and skill takes more time to develop and will require extensive practice.

Another of our goals as educators is to channel as much information as possible into long term memory so our students can eventually reach this level of skill. According to Chamot and O'Malley (1994) the challenge is to prepare the L2 students to express knowledge in working memory, acquired in either L1 or L2, procedurally through L2. A crucial factor in effecting this transition is the implementation of learning strategy instruction. In other words, in learning a complex cognitive skill there will be advantages to using modelled performance of the task as well as strategy training.

O'Malley and Chamot (1990) suggest that learning strategies or procedural knowledge in the learner's L1 could be transferred to the new conditions in the L2. They go on to say this is extremely difficult to do because of the added load to short-term memory processing requirements which are already burdened by trying to decode the new language. Thus, repetition and practice of the learning strategies can only be beneficial as they will enable them eventually to become more automatic, freeing up the short term memory to focus on other information.

Perhaps we can devise a way to get students to learn so they can use their long term memory – the part under the water – more, which will free up more of the working memory. We want to work on strategies to help get more of the content we are teaching into long term memory.

Strategies

What do we mean by strategies? The word 'strategy' comes from the Greek *strategos* that means 'deception' or 'to trick' (Town, 2006). It was first used in cognitive psychology in 1956 and, in applied linguistics, the strategy research dates back to 1966. There is a great deal of research that has been conducted on theoretical framework for language learning and this has led to a whole range of strategies used in vocabulary learning tasks, reading comprehension and writing.

There is no agreement on exactly what learning strategies are or how many of them there are and what they consist of. In essence, strategies are what learners do to

regulate their learning. Gagne (1985) describes it as skills by means of which learners regulate their own internal processes of attending, learning, remembering and thinking. O'Malley and Chamot (1990) say that learning strategies are 'special ways of processing information that enhance comprehension, learning or retention of the information'. In addition, O'Malley and Chamot advocate that certain strategies should be taught to all students and that different learners prefer to process information at different levels. We have found that learning strategies interact with the learners' existing communicative competence in order to enhance learning.

Oxford (1990) stresses the importance of cues for improving all four types of learning skills: reading, writing, listening and speaking. She goes on to suggest that building guessing skills step-by-step in students is important and that working on memory practice and asking students to share ideas for how they remember new vocabulary words is necessary. In addition, she recommends that teachers act as role models by thinking out loud and demonstrating to their students their own learning strategies. The teacher as a mediator helps students organise information and mental processes, thus helping the students to become autonomous learners.

Furthermore, students who do not seem to realise that a learning task or activity is not progressing well can be taught to monitor or check their comprehension and progress so they can identify where they are having difficulties and select problem-solving strategies to address the difficulties (Chamot and Kupper, 1989).

Learning strategies are difficult to observe and only by asking students can we discover which strategies are being used. It may be difficult for the student to articulate the strategy or to correctly identify exactly what they did. These strategies however need to be facilitated through teacher demonstration and modelling. It is important to provide multiple practice opportunities with the strategies so the students can use them autonomously.

Strategies should be based on the students' attitudes, beliefs, and stated needs. They should be chosen so they mesh with and support each other so that they fit the requirements of the language task, the learners' goals, and their style of learning. This approach should be integrated into regular L2 activities over a long period of time rather than taught as a separate, short intervention. Educators in content classes cannot simply ignore content for strategies and so a mixed approach must be used here.

Learning strategies should also not be permanently tied to the content or class but should aim towards transferable tasks beyond a given content or class. Oxford (1989) says that consideration needs to be given to different genders, cultural backgrounds, motivation, learning styles, and attitudes and beliefs. Thus, approaches should be individualised and allow students to develop mechanisms to evaluate their own progress and the value of the strategies in multiple tasks.

Krashen (1982) contends the focal point for an effective second language programme is the creation of situations in which students have opportunities for interaction. He went on to stress the importance of 'comprehensive input' in order for a person to acquire a second language. Swain (1985) affirmed the necessity for output. We need to work to combine these concepts in input and output to increase communicative competence. Ideally that would include work on facilitating interaction between students and the teacher thereby creating an environment rich in spontaneous and meaningful language. This could be done with the use of cooperative learning activities. Krashen

(1982) argues that cooperative learning is firmly rooted in language acquisition theory in that it focuses both on the provision of comprehensible input and the opportunity for producing output. Well-designed cooperative learning tasks involve the negotiation of meaning within a communicative context, an essential process for effective second language learning. Ideally in a cooperative learning environment, the environment should support student risk-taking and encourage them to assist one another.

Structured cooperative learning activities will provide the basic foundation for a well-managed classroom where students understand what is expected of them, what their roles are, and what the rules are, thereby creating a language learning environment ripe for success. Cooperative learning activities can also be an effective means of integrating students with special needs. Chamot (2004) says that ideally teachers should integrate strategy instruction into their course work and it should be included in all classes. She says this would make it more likely that students would transfer strategies learnt in one class to another class. Oxford (1990) says it is better if students can develop a wide repertoire of learning strategies. Therefore, learning multiple strategies would appear to be beneficial. Teachers provide increased amounts of naturalistic communication in their classroom, and the environment will be more conducive to a good language learning experience.

Learning strategies should be integrated into the learners' L2 activities over a period of time, not taught as a separate intervention. They should be transferable to future language tasks and work on memory practice, and the teachers should act as a role model. Learning strategy instruction can help learners to become better learners, become more independent and confident learners, and be more motivated as they begin to understand the relationship between the use of strategies and success in learning languages (Chamot and Kupper, 1989; Chamot and O'Malley, 1994). Learners without metacognitive approaches are essentially learners without direction or opportunity to review their progress, accomplishment and future directions (O'Malley, Chamot, Stewner-Mazanares, Russo, and Kupper 1985).

Imagine the increased difficulty for L2 students. The importance of tunnelling as much information as possible into long term memory and the necessity of comprehensible input and output needs a plan to improve the method of teaching strategies while also teaching content. This plan incorporates preparation, presentation, practice, evaluation and expansion. The preparation stage helps students identify the strategies they are already using by setting specific goals, and plan time to accomplish the tasks within the given time. Presentation models the learning strategy, talk about the usefulness, applications of the strategy through examples and how to look up a vocabulary word they encounter in a text. Taught that no single vocabulary strategy would work in every case, look for contextual cues for guessing the meaning of unknown words. Practice with an authentic learning task, recognise strategies available to them, how to recognise if a strategy is not working and how to move to another. Evaluation is through an evaluation of the student's own success in using learning strategies, using self-questioning, discussions about strategies' practice, checklists, open-ended questionnaires where students express their opinions about the usefulness of employing strategies. Finally, expansion uses strategies towards new contexts. Strategies that the teacher finds most effective and a result of individual combinations and interpretations that work in a particular setting, group or classroom. Part of the structure is to reduce

the time spent on checking strategies as the use of strategies will eventually change from factual knowledge to procedural and as a result become more automatic. The strategies need to be continuously reinforced by the teacher.

Any organism needs a rich and stimulating environment in order for its natural capacities to emerge. Is this how you would describe your classroom? Teachers need to awaken the natural curiosity of the students and stimulate their interest in exploring on their own. What students learn passively is quickly forgotten, but what students discover for themselves through natural curiosity and creative impulses will be remembered and serves as the study basis for further exploration, inquiry and perhaps even significant intellectual contributions (Chomsky, 1988).

Let us imagine a physicist who is trying to figure out what is happening inside the sun. The easy way to answer this question would be to put a laboratory inside the sun and perform experiments. Since this is not possible, one must look at the light that reaches us from the sun and try to imagine what is happening to produce that kind of light. This is very much like trying to figure out what is going on in the physical mechanisms of the brain. We can see the results outside, but we are only conjecturing about what goes on inside. Use common sense and use your experience and do not listen too much to the scientists unless you find what they say is really of practical value and of assistance in understanding the problems you face (Chomsky, 1988).

Repetition priming and the learning curve

A common lamentation among mathematics and science teachers is the seemingly endless need to repeat basic information. They just do not get it sometimes. Once a new concept is introduced, well explained, demonstrated and understood by the learner, the expectation is that the learner has 'got it'. But just a little while later, the understanding falls apart. The understanding is once again built up and later it again falls apart; if the situation of the problem changes, the understanding fails once again. It seems almost that each new situation results in a failure of the understanding. Teachers know that the context must be changed in order to increase the chance of making a connection within the scope of repetition. Certainly flowing between two languages makes the context changes more difficult for the learner.

What makes this particularly vexing is the teacher expectation that students should follow some kind of learning curve. A sample curve is given in Figure 5.

Does the learning curve given in Figure 5 match your experience with teaching and learning? The problem with this model of learning is that it is behaviourally-based on learning physical tasks and was not developed for higher levels of learning. The model was first applied to a study of aeronautical assembly line workers in 1936 by T. Wright (Wright, 1936). It is practically at the level of an urban myth that students should demonstrate such a common learning model. Indeed, it is so common that researchers regularly supersede within the curve more complicated approaches. Wightman and Lintern (1985), for example, suggest a format that systematically repeats earlier parts within a chain of learning on a learning curve for complicated tasks. The bottom line is that repetition is necessary to learning and that repetition still does not always improve learning.

Alternatively, Fischer and Rose point out that higher learning is best modelled by

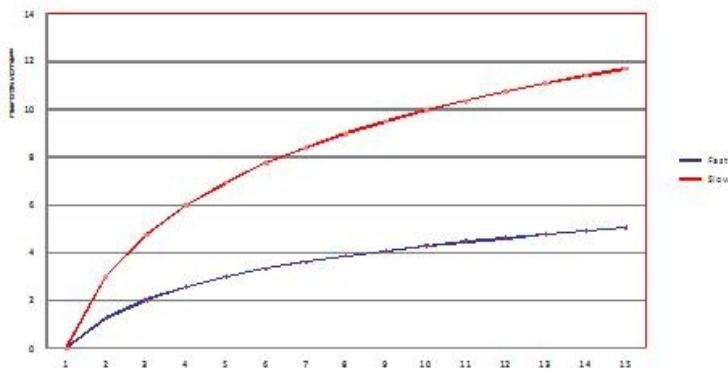


Figure 5: Sample (hypothetical) learning curve.

more of a cyclic process than an exponential–logarithmic one (Fischer and Rose, 1999). You learn a new understanding and it falls apart. Repetition is necessary and seems not to improve learning. This is typical of learning models. Each time there is a change in the situation, you start over. Thus, learners can seem to have grasped a concept at one point, but very quickly lose the ability. Fischer and Rose state that since this is the learning model expected, one should therefore design learning according to this model and not the traditional learning curve intelligently and one should use technology to increase access and offer repetition towards the goal. Thus, the learning curve in Figure 6 is a better match with our experiences in the classroom.

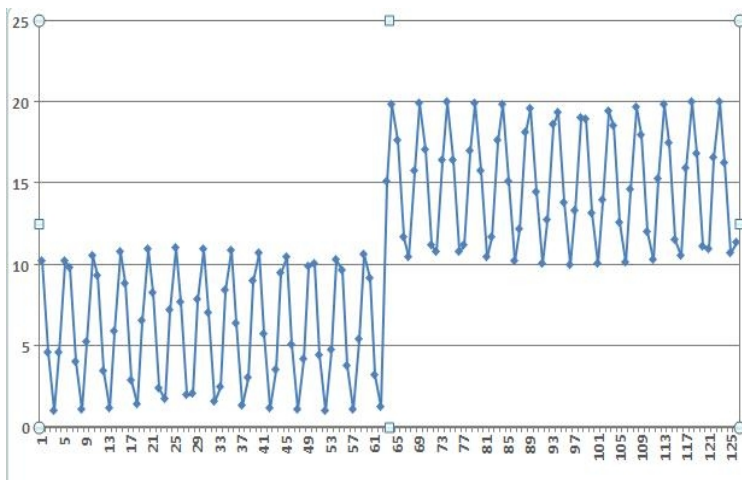


Figure 6: A learning curve that demonstrates a realistic cycle of higher learning.

Final note: Strategies and technology

Higher-level learning is an iterative and interactive process that builds up complexity, something process educators think of strongly (process education). Notice that it is repetition and priming that eventually cause a shift in learning from the lower level to the higher level. The keys in priming the shift are through understanding the student and the context of the material and making use of key items to make the material real, interesting, loud and colourful. Organise representation, perhaps using technology, to support and force pattern and organisation. Further, support should be given that keeps the learner at the optimal part of the learning curve. This means one should try to keep the learner at the top of the cycle. Knowing what characteristics are needed at the bottom of the next level helps the teacher to choose items that will prime the learner to jump levels. Finally, it seems reasonable to abandon the idea that this process is a smooth process built up of increasing concepts. The actual learning process is discontinuous and rough. Expect and understand that the learner will sometimes seem to have lost all advancement. Additional key characteristics of priming learning towards the next level include giving prototypic answers, structures, and learning strategies. Being repetitive and making good use of technology towards supporting both the current level and helping prime the next level is also recommended. Repeat in multiple contexts. For example, solve problems alternatively with a calculator, without a calculator, formula, no formula, both in and out of the multiple language setting. Practice and remind students thirty minutes before a test or examination of the material at hand. Finally, technology poses a number of possibilities. The polar bear and penguins in the title of this paper refer to a motivational video often used in our classrooms. Penguins dancing excitedly as students at the end of the week; the polar bears dragging themselves around like Monday (Sunday) morning office workers.



Figure 7: Image clips from Monday versus Friday video (source anonymous).

We have presented an analysis in miniature of the progression of how memory and learning supports recent trends using neural network modelling. The second language setting in mathematics and science is demonstrably more difficult for students and this fits the paradigm of memory and learning theory. The obstacles presented clearly sug-

gest that a reduction and/or consideration of the number of situational links are necessary to improve learning for L2 learners. We have also presented some strategies that may prove useful in the practical situation of our classrooms that help make the connection between types and levels in the network of memory. An alternative learning curve supports what we see in the classroom and suggests that repetition priming should be one of the tools in our classrooms, in addition to a plan of preparation, presentation, practice, evaluation and expansion. Effective use of technology in the mathematics, computing and science classroom necessarily takes advantage of the characteristics of repetition priming, but also presents possibilities in enriching and linking context. Further research into different methods and timing of repetition priming and the appropriate timings of technology would help promote informed decisions towards improving learning and memory.

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